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DEVELOPMENT, PRINCIPLES, AND APPLICATIONS OF INTERRUPTED QUENCH HARDENING

BY

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The hardening of steel is generally accomplished by one of the following methods: (*a*) Continuous cooling from above its critical temperature to room temperature usually in air, oil, or water; or (*b*) Interrupted quench hardening, variously termed Step Quenching, Martempering, or Marquenching.

Scientific heat treatment is a recent development which has its roots in the fundamental knowledge of the changes which occur when steel is quenched or otherwise cooled from above its critical temperature to room temperature. The commercial application of this fundamental knowledge has enabled us to obtain and control desired combinations of hardness, structure, and properties which a few years ago were not possible. Our knowledge of heat treating has been clarified through research and several new treatments have been developed. One of the most useful of these new treatments, now known as Martempering, is important commercially because it minimizes stress concentration and distortion and avoids cracking.

The Martempering treatment is so well known today that a detailed description of the process is hardly necessary. Suffice it to say that the method involves quenching the heated steel from above its critical temperature into a hot bath maintained at about 400° F. or above or within the range of martensite formation. The work is then held sufficiently long to equalize in temperature but not long enough to permit transformation at that temperature level. This is followed by slow cooling in air through the range of martensite formation to room temperature.

The earliest attempts at interrupted quench hardening may be

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traced back to 1879 when Richard Akerman (1)[1] dipped the austenitized steel into a lead bath followed by air cooling. Other early investigators including D. Lewis (2) and O. C. Trautman (3) might be cited. In the light of our present knowledge these early attempts appear to be largely empirical and limited in usefulness.

The writer is more than grateful to the kindly fates that brought early acquaintanceship with Martempering. Insofar as it is known, the treatment was first developed and brought under scientific control through the efforts of the writer starting in 1938 while serving as a hardening apprentice at the Simonds Saw & Steel Co. The treatment, which I originally termed Step Quenching, was first applied to the hardening of hacksaw blades of the 1¼ per cent carbon-1½ per cent tungsten type, resulting in straighter, tougher blades which cut 20 per cent better than regularly hardened saws. These efforts culminated in a U.S. Patent Application, Serial No. 320,998 filed Feb. 27, 1940 (4) which was eventually disallowed by the Patent Office. Figure 1 illustrates schematically three heat treatments: Conventional hardening, Austempering, and Step Quenching with reference to the transformation curves taken from the patent application.

Austempering is an isothermal treatment which consists in quenching rapidly through the pearlite forming temperature region down to a temperature above the range of martensite formation and then holding for a sufficient length of time to complete the transformation at that temperature level to a structure termed Bainite. This treatment results in moderate hardnesses generally about Rockwell C 50 to 55 which is appreciably below that obtainable on interrupted quench hardening.

The method previously used to harden the hacksaw blades consisted in heating in a hearth type furnace, followed by oil quenching and clamp straightening. The blades were placed in the furnace one at a time by means of a hooked poker about six feet long. After heating through, the hardener had to hook the small hole about one-eighth inch in diameter at one of the ends of the saw blade with a poker to withdraw the blades from the furnace for quenching in oil. It was a difficult task to hook the small holes, as the heated blades and furnace all appeared the same shade of red when the hardening temperature was attained. While I was a failure production-wise on this assignment, it did leave me with a strong desire to develop a better method of hardening hacksaw blades.

There were many difficulties and progress was slow as the new treatment I developed was too far ahead of its time to be appreciated. My formal training and degree were in chemistry and much of my time had to be devoted to learning the fundamentals of metallurgy. Also, I was assigned to production problems and routine laboratory work rather than research, so that the constant interference of other projects, many of an entirely different nature, became a major problem. However, a

[1] The boldface numbers in parentheses refer to the references appended to this paper.

clearly conceived idea of the new quenching method and what it was expected to accomplish kept me on the right track. Working in a new field, there are no established directions to follow and many cross roads appear which can only lead to blind alleys and negative results.

There were many other obstacles to overcome. The transformation curves constituting the fundamental technical knowledge which led to

FIG. 5

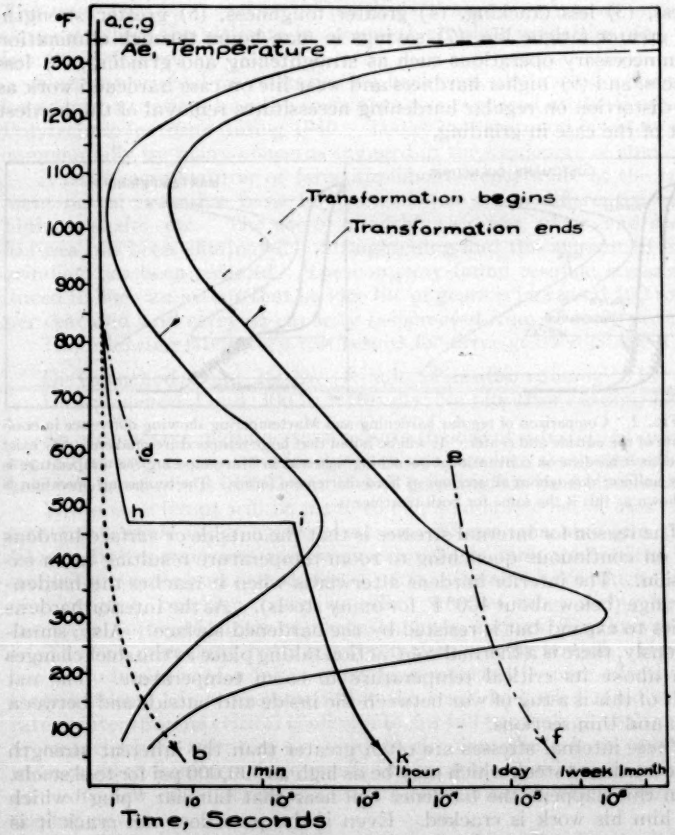

FIG. 1. Reproduction of Fig. 5 of U.S. Patent Application, Serial No. 320, 998, filed February 27, 1940.

the conception of Martempering, was misleading insofar as the transformation of austenite to martensite is concerned.

Contrary to accepted opinion at the time, this change is not an isothermal transformation as shown in the transformation diagram of Davenport and Bain, but is a change which depends on a lowering in temperature for its continuation. The classic investigation of Troiano and Greninger (5) conclusively proved this point.

Over traditional hardening, interrupted quench hardening offers a number of important advantages: (1) less distortion, (2) less internal stress, (3) less cracking, (4) greater toughness, (5) greater strength, (6) greater fatigue life, (7) savings in man hours through elimination of unnecessary operations such as straightening and grinding, (8) less rejects, and (9) higher hardness and wear life on case hardened work as the distortion on regular hardening necessitates removal of the hardest part of the case in grinding.

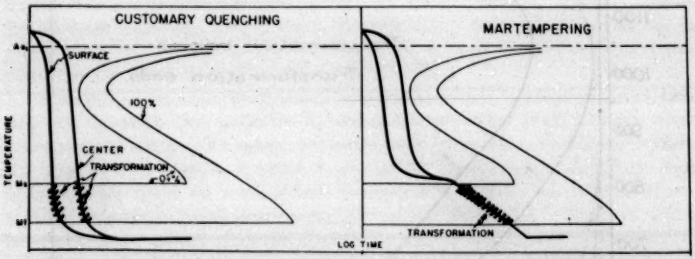

FIG. 2. Comparison of regular hardening and Martempering showing difference in cooling rate of the outside and center. It will be noted that large temperature gradients may exist in steel as it hardens on conventional quenching, whereas in Martempering the temperature is nearly uniform throughout all sections as hard martensite forms. The tempering operation is not shown as this is the same for both treatments.

The reason for internal stresses is that the outside or surface hardens first on continuous quenching to room temperature resulting in an expansion. The interior hardens afterwards when it reaches the hardening range (below about 400° F. for many steels). As the interior hardens it tries to expand but is resisted by the hardened surface. Also, simultaneously, there is a thermal contraction taking place as the steel changes from above its critical temperature to room temperature. The net result of this is a tug of war between the inside and outside and between thick and thin sections.

These internal stresses are often greater than the inherent strength of the hardened steel, which may be as high as 500,000 psi for tool steels. When this happens the hardener will hear that familiar "ping" which tells him his work is cracked. Even if the part does not crack it is common for the disruptive internal stresses to amount to as much as 90 per cent or more of the total strength of parts. This means that

only a small fraction of the calculated strength of hardened parts may be available to do useful work. Since we cannot conveniently measure the concentration of stress in hardened parts by non-destructive tests, it is often a gamble as to whether such parts will stand up or fail in service.

The interrupted quench hardening treatment attempts to equalize the temperature within parts before hardening proceeds on slow cooling in air. In this way the hardening proceeds uniformly throughout all sections of the part thus avoiding undesirable concentrations of stress. The treatment is, therefore, of particular value on parts of intricate shape or where the ultimate in accuracy, physical properties, and uniformity is desired.

Since my original investigation on hacksaws, other applications followed and a thesis (6) on the treatment was prepared at the Worcester Polytechnic Institute during 1940. Today the treatment is widely used commercially by many concerns engaged in the hardening of steel.

A large manufacturer of farm impliments reports use of the treatment on an extensive basis for transmission gears, differential gears, pinions, shafts, etc. The use of quenching presses, plugs, and special fixtures has been eliminated. Straightening and the amount of finish grinding has been reduced. The company found residual stresses reduced to such an extent that service life of gears is increased 100 to 200 per cent and load carrying capacity is increased from 15 to 20 per cent.

The following laboratory test results for drive gears is cited:

Die quenched: Load, 260 lb. Results: Pits after running 18 hr.
Hot quenched: Load, 300 lb. Results: No pits after running 100 hr.

An automotive manufacturer reports the use of interrupted quenching in hot salt on transmission gears where involute tooth distortion is held to plus or minus 0.0002 in. Tooth grinding has been eliminated.

While no attempt will be made to cite a complete list of uses of the treatment, some other applications are: 20-mm. machine gun parts, 40-mm. Bofors gun parts, tank engine camshafts, tank armor plate, tank torque converter parts, tank tread parts, aircraft clutch rings, armor piercing shot, bearings, races, spindles, clutches, meat slicing knives, raceways, outboard motor crankshafts, gears, springs, dies, knives. etc,

The hot quenching bath may be molten salt or hot oil. Hot salt has the advantage of a faster quenching rate and is more effective for large sections. It is necessary that the work be cooled rapidly, at a rate greater than its critical cooling rate, for full hardening. Salt pumps or motor driven agitators are used to circulate the salt to provide a more rapid and uniform hot quench. Separating chambers are provided on many new installations to separate contaminants which reduce the cooling power.

One field where commercial applications of the treatment will probably increase involves the hardening of brazed parts. The use of as-

semblies brazed with silver solder or copper has replaced expensive machining operations on many industrial applications. The brazed joints, however, are very weak at the temperatures used for hardening and may easily be ruptured by the severe temperature gradients encountered in traditional hardening practice. The interrupted quench, on the other hand, permits hardening of brazed assemblies which would otherwise be most difficult if not impossible.

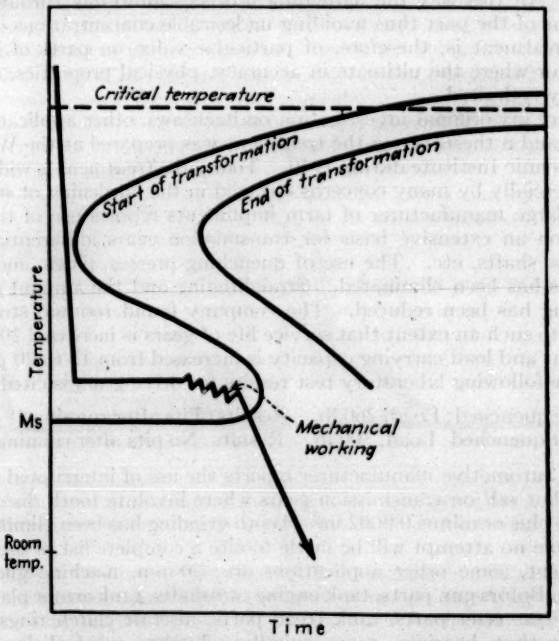

FIG. 3. Diagrammatic representation of the Step Quench Hot Working Method. Shot peening is an effective hot working method.

A new modification (8) of the interrupted quench treatment which I recently developed involves a combination of Step Quenching and mechanical working above or within the range where hardening occurs.

Shot peening is a common means of cold working metal parts to introduce beneficial surface compressive stress to increase fatigue life. Shot peening the metal while hot and still austenitic after removing from the low temperature bath above or at the Ms point results in a greater degree of compressive stress at the surface than may be imparted by conventional cold peening methods. For example, Almen

test strips 0.051 × ¾ × 3 in. shot peened to an arc height of 0.016 in. by conventional cold peening, showed an arc height of 0.029 in. when hot peened by the new method described and using the same intensity of peening. The greater curvature of the hot peened specimens is due to the greater degree of surface compressive stress.

In addition to the higher compressive stress and fatigue life the hot peening results in higher hardness and transformation of an undesirable constituent, retained austenite, from the surface. It has been found that mechanical working of the subcritical austenite results in a greater conversion to hard martensite than would result without the mechanical working. X-ray determinations of the volume per cent of retained austenite on specimens peened and unpeened show a conversion of up to about 80 per cent of the retained austenite as a result of hot peening.

Other forms of mechanical working other than shot peening may be used with beneficial results. While the Step Quench Hot Working method is still in the experimental stage it is expected that commercial applications of this treatment will follow.

The trend of hardening in modern industry is toward more extensive use of interrupted quench hardening and many feel that it will ultimately be more widely used than other methods of hardening steel. The use of Martempering—or Step Quenching as I still like to think of it—has enabled us to obtain greater strength and toughness from hardened parts together with a minimum of distortion, internal stress, and cracking.

Over the years the combined efforts of many interested in the science of metals and heat treating have transformed an age of stone into one of brass and later to one of iron and steel (**9, 10**). To prophesy the future is an uncertain and thankless task. However, it is to be expected that the interrupted quench principles will be one of the fundamental building blocks on which much of future hardening progress will be based.

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"Mylar"* Polyester Film.—The Du Pont Company will start construction early this year on a plant south of Circleville, Ohio, for manufacture of "Mylar" polyester film, a new product which was developed and is being made on an experimental basis in the company's Yerkes Research Laboratory in Buffalo.

"Mylar," an entirely new film with unusual strength, heat resistance and insulating qualities, was developed by Du Pont through one of its fundamental research programs. The development was announced in January, 1952. In its transparent form, "Mylar" looks like cellophane. It is in no sense a substitute for cellophane, however, but an entirely new product with distinct properties which appear to make it suitable for a series of new industrial uses.

Studies indicate that "Mylar" is a versatile material that will find major uses in different fields from those for which cellophane and other commercial films are most suitable. Because it has great strength and excellent electrical properties, which remain relatively constant over a wide range of temperatures and humidities, its most promising immediate field appears to be electrical insulation, in such applications as motors, condensers, cables, coils, and transformers.

Also, it should widen the uses of tapes for carton-strapping, reinforcement, and other industrial applications, and is promising as a base for long-lasting magnetic sound-recording tape. It is expected to be laminated with other materials, and may be metallized by depositing a microscopically thin layer of aluminum or other metal on it. Other uses, which will require further research and development, include packaging and plastic glazing. Among the possibilities in the latter field are light-weight storm windows and tack-on glazing for poultry houses and other farm buildings.

Many fields remain to be explored, and full development of the material's potentialities must await completion of the Circleville plant, since the film will be available only in limited quantity until then.

Modular Office Furniture.—At an American Management Association conference late in 1949, E. I. du Pont de Nemours & Co. disclosed spectacular benefits from modular office furniture the company's own engineers had designed. Some time later, du Pont licensed seven manufacturers to produce the furniture. First on the market was Korda Industries' version, known as "KORDAroom."

Korda Industries has now issued a report on the use of the furniture in creating man-hours and space. Specific case histories are given, including experience of American Cyanamid, Colgate-Palmolive-Peet, Forbes Magazine, International Latex, Monsanto Chemical, Sterling Winthrop Research Institute.

Keystone of the KORDAroom system is a range of modules affording 100,000 variations to fit individual office needs. A handy space-selector chart is a feature of the report.

Address inquiries to E. L. Jamison, Korda Industries, 20 West 46th Street, New York 36, N. Y.

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* Du Pont trade mark.

[1] See this JOURNAL, Vol. 250, No. 5, p. 418 (1950).

ON TORSIONAL-FLEXURAL BUCKLING OF COLUMNS

BY

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INTRODUCTION

Since several ingenious analyses of torsional-flexural buckling of columns (1, 2, 3, 4, 5, 6),[2] have appeared since H. Wagner originated the theory in 1929, another contribution to the literature on the subject requires an explanation. The distinguishing feature of the following treatment is that it does not adduce a theory of non-uniform torsion; the equations for torsional-flexural buckling of columns are derived analytically from the fundamental equations of elasticity and the variational principles of mechanics. Agreement with the Kappus theory is not obtained, unless a term that is inversely proportional to the square of the length of the column is neglected. The effect of this approximation is illustrated by an example.

The author is indebted to his friend, Dr. Cornelius Lanczos, for the general theory of elastic stability upon which the analysis is based. In 1943, Lanczos developed this theory, in connection with the problem of buckling of cylindrical shells under axial compression. Unfortunately, he was diverted from his studies in elasticity, and his work in this field has not been published; consequently, his general theory is presented briefly.

A stationary conservative mechanical system is in stable equilibrium if, and only if, its potential energy V has a relative minimum; that is, $\Delta V > 0$ for any small virtual displacement of the system that is consistent with the constraints. For an elastic system, $V = U + \Omega$, where U is the strain energy, and Ω is the potential energy of the external forces. Consequently, $\Delta V = \Delta U + \Delta\Omega$. If the system has linear elasticity,

$$\Delta U = \delta U + \frac{1}{\underline{2}}\,\delta^2 U + \frac{1}{\underline{3}}\,\delta^3 U + \frac{1}{\underline{4}}\,\delta^4 U$$

where $\delta^n U$ (the n-th variation of U) is the volume integral of a homogeneous polynomial of n-th degree in the components of the virtual displacement vector and its first derivatives. In many important cases, Ω depends linearly on the virtual displacements; then $\Delta\Omega = \delta\Omega$, and

$$\Delta V = \delta\Omega + \delta U + \frac{1}{\underline{2}}\,\delta^2 U + \cdots.$$

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[2] The boldface numbers in parentheses refer to the references appended to this paper.

For any equilibrium configuration, $\delta\Omega + \delta U = 0$. This is the principle of virtual work. Consequently, since $\delta^2 U$ depends on all components of the virtual displacement vector, it has the same sign as ΔV, provided that the virtual displacements are small. Therefore, when $\delta^2\Omega \equiv 0$, a necessary and sufficient condition for stability of equilibrium is that $\delta^2 U$ be positive definite; that is, $\delta^2 U > 0$ for all virtual displacements that are consistent with the constraints.

When the type of loading on an elastic structure is specified, the external loads are determined completely by the magnitude P of the total load. For small values of P, $\delta^2 U$ is positive definite, but, for large values of P, $\delta^2 U$ is indefinite. The buckling load P_{cr} is the value of P for which $\delta^2 U$ experiences this change of character.

If (ξ, η, ζ) is the displacement vector that defines the given equilibrium configuration, and (u, v, w) is the incremental virtual displacement vector, the total displacement vector is $(\xi + u, \eta + v, \zeta + w)$. Hence, if rectangular coordinates (x, y, z) are used, the exact expressions (7) for the strain components are

$$\begin{aligned}
\epsilon_x &= \xi_x + u_x + \tfrac{1}{2}(\xi_x + u_x)^2 + \tfrac{1}{2}(\eta_x + v_x)^2 + \tfrac{1}{2}(\zeta_x + w_x)^2 \\
\epsilon_y &= \eta_y + v_y + \tfrac{1}{2}(\xi_y + u_y)^2 + \tfrac{1}{2}(\eta_y + v_y)^2 + \tfrac{1}{2}(\zeta_y + w_y)^2 \qquad (1) \\
\epsilon_z &= \zeta_z + w_z + \tfrac{1}{2}(\xi_z + u_z)^2 + \tfrac{1}{2}(\eta_z + v_z)^2 + \tfrac{1}{2}(\zeta_z + w_z)^2 \\
\gamma_{yz} &= \eta_z + v_z + \zeta_y + w_y + (\xi_y + u_y)(\xi_z + u_z) \\
&\quad + (\eta_y + v_y)(\eta_z + v_z) + (\zeta_y + w_y)(\zeta_z + w_z) \\
\gamma_{zx} &= \xi_z + u_z + \zeta_x + w_x + (\xi_z + u_z)(\xi_x + u_x) \\
&\quad + (\eta_z + v_z)(\eta_x + v_x) + (\zeta_z + w_z)(\zeta_x + w_x) \\
\gamma_{xy} &= \eta_x + v_x + \xi_y + u_y + (\xi_x + u_x)(\xi_y + u_y) \\
&\quad + (\eta_x + v_x)(\eta_y + v_y) + (\zeta_x + w_x)(\zeta_y + w_y)
\end{aligned}$$

where subscripts (x, y, z) on $(u, v, w, \xi, \eta, \zeta)$ denote partial derivatives. The strain energy of the system is

$$U + \Delta U = \tfrac{1}{2}G \iiint \left\{ \frac{2\nu}{1 - 2\nu}(\epsilon_x + \epsilon_y + \epsilon_z)^2 + 2(\epsilon_x^2 + \epsilon_y^2 + \epsilon_z^2) + (\gamma_{yz}^2 + \gamma_{zx}^2 + \gamma_{xy}^2) \right\} dx\, dy\, dz. \qquad (2)$$

The part of this expression that is quadratic in derivatives of (u, v, w) is $\delta^2 U$.

Lanczos pointed out that, when the quadratic terms in Eq. 1 are neglected, $\delta^2 U$ is invariably positive definite. Consequently, in cases for which $\delta^2\Omega \equiv 0$, the phenomenon of buckling does not lie within the scope of the linear theory of elasticity. This conclusion might have been anticipated from the uniqueness theorem of linear elasticity theory.

FORMULATION OF THE COLUMN PROBLEM

A prismatic or cylindrical elastic bar with a simply connected cross section is referred to rectangular coordinates (x, y, z), such that the z-axis is the centroidal axis of the bar. The ends of the bar are at $z = 0$ and $z = L$.

Modes of buckling are considered for which the transverse stresses $\sigma_x, \sigma_y, \tau_{xy}$ are zero. These conditions exclude the phenomenon of local crippling, for crippling entails appreciable transverse bending of the cross section, with consequent transverse stresses. The assumption $\sigma_x = \sigma_y = \tau_{xy} = 0$ must be restricted to simply connected cross sections. For example, if an axially loaded cylindrical shell buckles in any way, other than as an Euler column, circumferential bending or hoop action occurs.

The conditions $\sigma_x = \sigma_y = \tau_{xy} = 0$ yield $\epsilon_x = \epsilon_y = -\nu\epsilon_z$ and $\gamma_{xy} = 0$. Consequently, Eq. 2 reduces to

$$U + \Delta U = \tfrac{1}{2}G \int\int\int \{2(1 + \nu)\epsilon_z^2 + \gamma_{xz}^2 + \gamma_{yz}^2\} dx\, dy\, dz. \quad (3)$$

Substitution of Eq. 1 into Eq. 3 yields the expression for $U + \Delta U$ in terms of $(u, v, w, \xi, \eta, \zeta)$. The part of this expression that does not contain (u, v, w) cancels with U on the left side of the equation. The part that is quadratic in the derivatives of (u, v, w) is $\delta^2 U$. If the initial state of deformation of the bar is determined by the linear theory of elasticity,

$$\xi = \nu\epsilon x, \qquad \eta = \nu\epsilon y, \qquad \zeta = -\epsilon z$$

where ϵ is the initial axial compression strain. Consequently, if the square of ϵ is neglected, and if first powers of ϵ are neglected when they are added to terms of the order of magnitude of unity, there results (disregarding the irrelevant factor $\frac{1}{2}G$)

$$\delta^2 U = -2(1 + \nu)\epsilon \int\int\int (u_z^2 + v_z^2) dx\, dy\, dz + \int\int\int \{2(1 + \nu)w_z^2 + (u_z + w_x)^2 + (v_z + w_y)^2\} dx\, dy\, dz. \quad (4)$$

This expression is positive definite if ϵ is small, but it becomes indefinite if ϵ is large. The problem is to determine the critical compression strain $\epsilon = \epsilon_{cr}$ for which this change occurs, when (u, v, w) are any regular functions of (x, y, z) that conform to the conditions $\sigma_x = \sigma_y = \tau_{xy} = 0$ and the forced boundary conditions.

An upper bound for ϵ_{cr} can be obtained by substituting into Eq. 4 any specific functions (u, v, w) that satisfy the forced boundary conditions and the conditions $\sigma_x = \sigma_y = \tau_{xy} = 0$, and setting $\delta^2 U = 0$. This method may be employed in any elastic stability problem.

DERIVATION OF THE DIFFERENTIAL EQUATION

A significant simplification results if the conditions $\sigma_x = \sigma_y = \tau_{xy} = 0$ are replaced by $\epsilon_x = \epsilon_y = \gamma_{xy} = 0$. This means that the cross sections are merely translated and rotated in their planes. This assumption is not consistent, unless $\nu = 0$. Consequently, the manner in which Poisson's ratio enters into the torsional buckling equations must be viewed with suspicion; however, for correlation with the Kappus theory, Poisson's ratio is retained.

The conditions $\epsilon_x = \epsilon_y = \gamma_{xy} = 0$ yield

$$u = \alpha + \gamma y, \qquad v = \beta - \gamma x \tag{5}$$

where (α, β, γ) are functions of z alone.

Tentatively regarding u and v as known, we determine w to minimize $\delta^2 U$. The second integral in Eq. 4 is denoted by Λ. The first variation of this integral, corresponding to a variation of w, is

$$\delta\Lambda = 2\int\int\int \{2(1+\nu)w_z\delta w_z + (u_z + w_x)\delta w_x + (v_z + w_y)\delta w_y\}\,dx\,dy\,dz.$$

Transformation of this integral by the divergence theorem yields

$$\begin{aligned}\delta\Lambda = &-2\int\int\int \{w_{xx} + w_{yy} + 2(1+\nu)w_{zz}\}\delta w\,dx\,dy\,dz \\ &+ 2\int\int \{(u_z + w_x)\cos(n,x) + (v_z + w_y)\cos(n,y) \\ &\qquad + 2(1+\nu)w_z\cos(n,z)\}\delta w\,dS,\end{aligned} \tag{6}$$

where (n, x), (n, y), (n, z) are the direction angles of the outward normal to the surface of the bar. The surface integral extends over the lateral surface and the ends of the bar. On the end faces, $\cos(n, x) = \cos(n, y) = 0$, and, on the lateral surface, $\cos(n, z) = 0$.

The volume integral in Eq. 6 must vanish. Consequently, w is a solution of the differential equation,

$$w_{xx} + w_{yy} + 2(1+\nu)w_{zz} = 0. \tag{7}$$

The lateral surface of the bar is free from constraint. Consequently, by Eq. 6, the boundary condition for the lateral surface is

$$(\alpha' + \gamma' y + w_x)\cos(n,x) + (\beta' - \gamma' x + w_y)\cos(n,y) = 0$$

or

$$\frac{dw}{dn} = -\frac{d}{ds}[\alpha' y - \beta' x + \tfrac{1}{2}\gamma'(x^2 + y^2)] \tag{8}$$

where dw/dn is the directional derivative along the outward normal to the surface, and d/ds denotes the derivative with respect to arc length on the periphery of the cross section.

If the column is clamped at the ends, the end conditions are $\alpha = \beta = \gamma = w = 0$. If it is loaded by point forces at the centroids of the end sections, and if rotation of the ends is prevented (pin-ended case), the quantities (α, β, γ) again vanish at the ends, and Eq. 6 yields the natural boundary condition, $w_z = 0$, for the end sections.

PIN-ENDED COLUMN

For the pin-ended column, the variable z may be separated from the variables (x, y) by Fourier series. Since the problems pertaining to the individual terms of the series are separated, only single typical terms of the series need be considered. Consequently,

$$\alpha = a \sin \frac{m\pi z}{L}, \qquad \beta = b \sin \frac{m\pi z}{L}, \qquad \gamma = c \sin \frac{m\pi z}{L} \tag{9}$$

where (a, b, c) are constants, and m is a positive integer. These functions satisfy the end conditions, $u = v = 0$. The solution of Eqs. 7 and 8 that satisfies the natural end condition, $w_z = 0$, is of the form

$$w = F(x, y) \cos \frac{m\pi z}{L}, \tag{10}$$

where $F(x, y)$ is a solution of the differential equation

$$F_{xx} + F_{yy} - 2(1 + \nu)(m^2\pi^2/L^2)F = 0 \tag{11}$$

with the boundary condition

$$\frac{dF}{dn} = -\frac{m\pi}{L}\frac{d}{ds}[ay - bx + \tfrac{1}{2}c(x^2 + y^2)]. \tag{12}$$

The function $F(x, y)$ is determined uniquely by Eqs. 11 and 12. Evidently, $F(x, y)$ is a homogeneous linear function of (a, b, c).

Equation 4 now yields the following expression for $\delta^2 U$:

$$\delta^2 U = -\epsilon[A(a^2 + b^2) + I_p c^2] + \int\int F^2\, dx\, dy + \frac{1}{2(1 + \nu)} \int\int \left\{\left[(a + cy) + \frac{LF_x}{m\pi}\right]^2 + \left[(b - cx) + \frac{LF_y}{m\pi}\right]^2\right\} dx\, dy \tag{13}$$

where A is the cross-sectional area of the column, and I_p is the polar moment of inertia of the cross section about its centroid. Accordingly, $\delta^2 U$ is a homogeneous quadratic function of (a, b, c); that is,

$$\delta^2 U = a_{11}a^2 + a_{22}b^2 + a_{33}c^2 + 2a_{23}bc + 2a_{31}ca + 2a_{12}ab. \quad (14)$$

By the theory of quadratic forms, $\delta^2 U$ is positive definite if, and only if,

$$a_{11} > 0, \quad \begin{vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{vmatrix} > 0, \quad \begin{vmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{vmatrix} > 0 \quad (15)$$

where, by definition, $a_{ij} = a_{ji}$. The column buckles if any of these three conditions is violated for any positive integer m. It appears likely that these conditions are satisfied for all m, if they are satisfied for $m = 1$.

RELATION TO THE KAPPUS THEORY

The Kappus equations are obtained, if the last term in Eq. 11 is neglected. This appears to be a reasonable approximation, since L is ordinarily large compared to the dimensions of a cross section. It is convenient to introduce the substitution,

$$F(x, y) = -\frac{m\pi}{L}[ax + by + c\psi(x, y)]. \quad (16)$$

Then, if the last term in Eq. 11 is neglected,

$$\psi_{xx} + \psi_{yy} = 0 \quad (17)$$

and the boundary condition is

$$\frac{d\psi}{dn} = \tfrac{1}{2}\frac{d}{ds}(x^2 + y^2). \quad (18)$$

In view of Eqs. 17 and 18, the function ψ is identified as the warping function of the Saint Venant torsion theory. The solution of Eqs. 17 and 18 contains an arbitrary additive constant. This loss of uniqueness results from the discarding of the last term in Eq. 11. The additive constant must be chosen to minimize $\delta^2 U$. This condition is satisfied if the mean value of ψ is zero; that is,

$$\int\int \psi dx\, dy = 0. \quad (19)$$

V. 19

The expression for $\delta^2 U$ (Eq. 13) now becomes

$$\delta^2 U = -\epsilon[(a^2 + b^2)A + c^2 I_p] + \int\int \left\{ \frac{m^2\pi^2}{L^2}(ax + by + c\psi)^2 + \frac{c^2}{2(1+\nu)}[(\psi_x - y)^2 + (\psi_y + x)^2] \right\} dx\, dy. \quad (20)$$

It is shown in the Saint Venant theory of torsion that[3]

$$\int\int [(\psi_x - y)^2 + (\psi_y + x)^2] dx\, dy = J \quad (21)$$

where GJ is the torsional stiffness of the bar. Three section constants of Kappus are defined as follows:

$$\Gamma = \int\int \psi^2 dx\, dy, \quad R_x = \int\int y\psi dx\, dy, \quad R_y = \int\int x\psi dx\, dy. \quad (22)$$

Consequently, the coefficients in Eq. 14 are

$$a_{11} = I_{yy} - \frac{AL^2\epsilon}{m^2\pi^2}, \quad a_{22} = I_{xx} - \frac{AL^2\epsilon}{m^2\pi^2}$$
$$a_{33} = \Gamma + \frac{JL^2}{2(1+\nu)m^2\pi^2} - \frac{I_p L^2\epsilon}{m^2\pi^2} \quad (23)$$
$$a_{12} = a_{21} = I_{xy}, \quad a_{13} = a_{31} = R_y, \quad a_{23} = a_{32} = R_x,$$

where I_{xx}, I_{yy}, and I_{xy} are the moments and product of inertia with respect to the x- and y-axes. With these coefficients, Eq. 15 is identical to the result of Kappus. It is to be noted that $a_{13} = 0$ if the section is symmetrical about the x-axis, and $a_{23} = 0$ if it is symmetrical about the y-axis.

EULER BUCKLING

For the Euler type of buckling, there is no rotation of the cross sections; that is, $c = 0$. The validity of Eq. 16 may be questioned in this case. However, if $c = 0$, and if the last term in Eq. 11 is neglected, the solution of Eqs. 11 and 12 is $F(x, y) = -(m\pi/L)(ax + by)$. Consequently, Eq. 16 is satisfied, when $c = 0$.

Since $c = 0$, the coefficients with index 3 are irrelevant. Accordingly, the criterion for stability (Eq. 15) reduces to

$$a_{11} > 0, \quad \begin{vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{vmatrix} > 0$$

or

$$I_{yy} - \frac{AL^2\epsilon}{m^2\pi^2} > 0 \quad (24)$$
$$\left(I_{yy} - \frac{AL^2\epsilon}{m^2\pi^2}\right)\left(I_{xx} - \frac{AL^2\epsilon}{m^2\pi^2}\right) - I_{xy}^2 > 0.$$

[3] See Appendix.

Now $I_{xx} + I_{yy} = I_1 + I_2$ and $I_{xx}I_{yy} - I_{xy}^2 = I_1 I_2$, where I_1 and I_2 are the principal moments of inertia. Let $I_2 \geqq I_1$. Then, since $I_2 \geqq I_{yy}$, Eq. 24 yields the following criterion for stability:

$$I_1 - \frac{AL^2\epsilon}{m^2\pi^2} > 0, \quad I_2 - \frac{AL^2\epsilon}{m^2\pi^2} > 0.$$

Consequently, the critical strain is

$$\epsilon_{cr} = \frac{\pi^2 I_1}{AL^2}.$$

This is the well-known Euler formula.

PURE TORSIONAL BUCKLING

If the coordinate axes are oriented so that $I_{xy} = 0$, and if the cross section is symmetrical about the x- and y-axes, Eq. 15 reduces to $a_{11} > 0$, $a_{22} > 0$, $a_{33} > 0$. The first two conditions yield the Euler formula for bending about the x- and y-axes. The condition $a_{33} = 0$ yields

$$\epsilon_{cr} = \frac{1}{I_p}\left[\frac{J}{2(1+\nu)} + \frac{\pi^2\Gamma}{L^2}\right]. \tag{25}$$

This is Wagner's formula for pure torsional buckling.

EXAMPLE OF COLUMN WITH CLAMPED ENDS

A column with a circular cross section and clamped ends is considered. The last term in Eq. 7 (which is neglected in the Kappus theory) will be retained, so that an indication of the effect of this term is obtained. An upper bound for the critical compression strain will be determined by means of the Euler displacements,

$$\alpha = u = -\frac{L}{2\pi}\left(1 - \cos\frac{2\pi z}{L}\right), \quad v = 0, \quad \beta = \gamma = 0. \tag{26}$$

For cylindrical coordinates, Eq. 7 is

$$w_{rr} + \frac{1}{r}w_r + \frac{1}{r^2}w_{\theta\theta} + 2(1+\nu)w_{zz} = 0. \tag{27}$$

A solution is obtained with

$$w = f(r)\cos\theta\sin\frac{2\pi z}{L}. \tag{28}$$

Equations 27 and 28 yield

$$f'' + \frac{1}{r} f' - \left(K^2 + \frac{1}{r^2}\right) f = 0, \tag{29}$$

where $K = \frac{2\pi}{L}\sqrt{2(1+\nu)}$. The solution of Eq. 29 that is finite for $r = 0$ is $f(r) = C_1 I_1(Kr)$, where I_1 is the modified Bessel function of the first kind, and C_1 is a constant of integration. By virtue of the power series for I_1, this solution may be written as follows:

$$f(r) = C_1\left[\frac{Kr}{2} + \frac{K^3r^3}{16} + \frac{K^5r^5}{384} + \frac{K^7r^7}{18432} + \cdots\right]. \tag{30}$$

The radius of the column is specified to be 1 unit. Then the boundary condition (Eq. 8) becomes $f'(1) = 1$. Hence, by Eq. 30,

$$C_1K = 2 - \frac{3K^2}{4} + \frac{11K^4}{48} - \frac{313K^6}{4608} + \cdots. \tag{31}$$

Equation 4 yields

$$\delta^2U = 1 - 2(1+\nu)\epsilon + K^2\int_0^1 rf^2\,dr - 2\int_0^1 (rf' + f)\,dr + \int_0^1 (rf'^2 + f^2/r)\,dr.$$

After some routine calculations, this yields

$$\delta^2U = -2(1+\nu)\epsilon + \frac{K^2}{4} - \frac{7K^4}{96} + \cdots. \tag{32}$$

The buckling criterion is $\delta^2U = 0$. This yields

$$\epsilon_{cr} < \frac{\pi^2}{L^2} - \frac{7\pi^4(1+\nu)}{3L^4} + \cdots.$$

The inequality sign is written because the analysis merely gives an upper bound for ϵ_{cr}, due to the fact that several assumptions were made, concerning the virtual displacements.

Since the radius of the column is 1 unit, the radius of gyration is $\rho = \frac{1}{2}$. Consequently, for a column with any radius,

$$\epsilon_{cr} < 4\pi^2(\rho/L)^2 - \frac{112\pi^4}{3}(1+\nu)(\rho/L)^4 + \cdots. \tag{33}$$

The Euler formula is obtained if only the first term in Eq. 33 is retained. This formula may be written as follows:

$$\epsilon_{cr} = C\pi^2(\rho/L)^2,$$

where C is an "end-fixity factor." Equation 33 yields

$$C < 4 - \frac{28(1+\nu)}{3}\epsilon_{cr} + \cdots. \tag{34}$$

Equation 34 shows that the end fixity of the Euler theory for a column with clamped ends ($C = 4$) is not quite attainable. The longer the column, the closer the end fixity $C = 4$ can be approached, since the last term in Eq. 11 is less important for long columns.

CONCLUDING REMARKS

The example of the last section suggests that the last term in Eq. 11 is usually negligible, although further studies of the effects of this term are desirable. When this term is neglected, the buckling stress of a pin-ended column is determined by the Kappus equations, (15) and (23).

For a column with clamped ends, we obtain an upper bound for the buckling stress by means of the following deflection functions:

$$\alpha = a\left(1 - \cos\frac{2\pi z}{L}\right), \quad \beta = b\left(1 - \cos\frac{2\pi z}{L}\right), \quad \gamma = c\left(1 - \cos\frac{2\pi z}{L}\right).$$

These equations lead to Eqs. 15 and 23, with $m = 2$. Consequently, a column with clamped ends is approximately equivalent to a pin-ended column of half the length.

The function ψ is altered by a linear term in x and y, if the origin is displaced. Consequently, the constants (R_x, R_y, Γ) depend on the location of the origin. In our theory, the origin has been placed at the centroid of the cross section. The shear center and the center of twist have not been considered.

If the column is subjected to a uniform twist of unit magnitude, the displacements are

$$u = -yz, \quad v = xz, \quad w = \psi.$$

Consequently,

$$\frac{\tau_{xz}}{G} = \psi_x - y, \quad \frac{\tau_{yz}}{G} = \psi_y + x. \tag{35}$$

Goodier (5) employed these equations to calculate ψ, as follows:

The increment of ψ, corresponding to increments (dx, dy), is

$$d\psi = \psi_x dx + \psi_y dy = \frac{1}{G}(\tau_{xz}dx + \tau_{yz}dy) + (y\,dx - x\,dy).$$

Converting to polar coordinates (r,θ), we have

$$y\,dx - x\,dy = -x^2\,d(y/x) = -x^2 d(\tan\theta) = -r^2 d\theta = -2d\omega,$$

where $d\omega$ is the element of area swept out by the radius vector r, when its end point experiences the displacement (dx, dy). Consequently, if C is a path that leads from a fixed point P_0 in the cross section to a variable point P, the value of ψ at point P is

$$\psi = \frac{1}{G}\int_C \tau ds - 2\int_C d\omega + \text{constant}, \tag{36}$$

where the first term is the line integral of the tangential component of the shearing stress vector on the path C. The additive constant must be chosen so that the mean value of ψ is zero.

Equation 36 enables us to determine ψ readily, if we can follow paths of integration for which $\tau = 0$. The center line of a thin open cross section, and any normal to the center line, satisfy this condition approximately. The point P_0 may be defined to be the intersection of the center line of the cross section with the x-axis. Then, if the cross section is symmetrical with respect to the x-axis, the additive constant in Eq. 36 is zero.

For a thin open section, an approximation to ψ may be obtained with the assumption that ψ is constant through the thickness of the section. Then ψ need be evaluated only for points on the center line of the cross section.

When ψ has been determined, the constants (R_x, R_y, Γ, J) may be computed by Eqs. 21 and 22. A well-known approximate formula for J for a thin open section with constant thickness t, and developed width b, is

$$J = \frac{1}{3}bt^3.$$

Acknowledgment

The general theory of elastic stability that forms the basis of the analysis was developed by Cornelius Lanczos in an unpublished manuscript in 1943.

APPENDIX

In view of Eq. 35, we have

$$J = \int\int [x(\psi_y + x) - y(\psi_x - y)]dx\,dy.$$

This is equivalent to Eq. 21, since

$$\int\int [\psi_y(\psi_y + x) + \psi_x(\psi_x - y)]dx\,dy = 0.$$

This can be shown by Green's theorem, with the aid of Eqs. 17 and 18.

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SOME APPLICATIONS OF PHOTIC FIELD THEORY

BY

PARRY MOON[1] AND DOMINA EBERLE SPENCER[2]

In a previous paper (1)[3], the theory of the photic field was developed and its practical possibilities in the calculation of radiant power and light were mentioned. The present paper continues this work by outlining some applications of photic field theory. In many cases, results are obtained more easily by the new method than by the classical method of surface integration.

ELEMENTARY SOURCES

As a trivial example that illustrates the use of a quasipotential, consider the photic field produced by an elementary (point) source. In this, as in all the examples of the paper, a non-dissipative and non-scattering medium is postulated. Use spherical coordinates (r, θ, ψ) with the source at the origin, Fig. 1, and consider the intensity distribution $I(\theta, \psi)$ from the source. Then at an arbitrary point P, the pharosage vector is

$$\mathbf{D} = \mathbf{a}_r \frac{I(\theta, \psi)}{r^2} \tag{1}$$

where $\mathbf{a}_r$ is a unit vector in the direction $\overline{OP}$.

By Theorem 12 (1), a quasipotential exists and Laplace's equation applies:

$$\nabla^2\Phi = \frac{d^2\Phi}{dr^2} + \frac{2}{r}\frac{d\Phi}{dr} = 0. \tag{2}$$

The general solution is

$$\Phi = A + \frac{B}{r}, \tag{3}$$

as in electrostatics. Differentiation gives

$$\nabla\Phi = \mathbf{a}_r \frac{d\Phi}{dr} = -\mathbf{a}_r \frac{B}{r^2}.$$

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[3] The boldface numbers in parentheses refer to the references appended to this paper.

But

$$\mathbf{D} = -\frac{1}{\zeta}\nabla\Phi,$$

so

$$\mathbf{D} = \mathbf{a}_r \frac{I(\theta, \psi)}{r^2} = \mathbf{a}_r \frac{B}{\zeta r^2}.$$

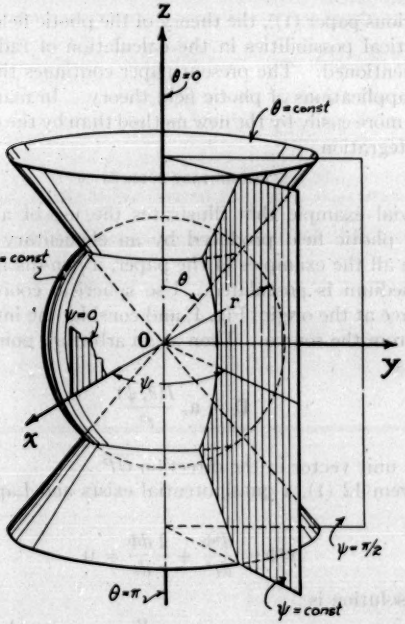

FIG. 1.

Therefore, the function ζ is determined by the relation,

$$\frac{B}{\zeta} = I(\theta, \psi). \tag{4}$$

Suppose, for instance, that the source is an element of perfectly diffusing surface so that

$$I = I_0|\cos\theta|.$$

Then from Eq. 4,

$$B = I_0, \quad \zeta = 1/|\cos\theta|.$$

The zero of Φ is arbitrary. Suppose Φ is taken equal to zero at $r \to \infty$. Then Eq. 3 becomes

$$\Phi = \frac{I_0}{r}, \tag{4a}$$

showing that the surfaces of equal quasipotential are concentric spheres about the source. Unlike the corresponding electrostatic problem, however, the photic **D**-vectors vary along an equipotential:

$$\mathbf{D} = \mathbf{a}_r I_0 \frac{\cos\theta}{r^2}. \tag{5}$$

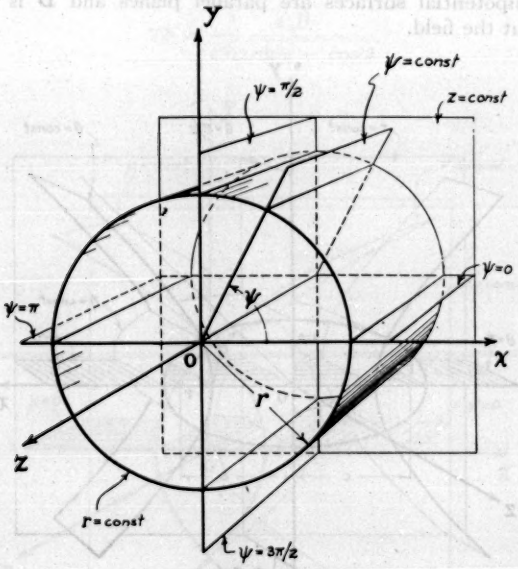

FIG. 2.

SURFACE SOURCES OF UNIFORM HELIOS

Plane Source

An infinite plane source of uniform helios H produces a photic field that is irrotational (Theorem 16). Laplace's equation is

$$\nabla^2\varphi = \frac{d^2\varphi}{dx^2} = 0,$$

whose solution is

$$\varphi = A + Bx. \tag{6}$$

By Theorem 18, the **D**-vector is constant everywhere on the luminous surface:

$$\mathbf{D} = \mathbf{a}_x H \quad \text{if } x = 0,$$

where $\mathbf{a}_x$ is a unit vector in the x-direction. Also, let $\varphi = 0$ at $x = 0$. These two boundary conditions evaluate the constants of Eq. 6, giving at any point in the field,

$$\begin{cases} \varphi = -Hx, \\ \mathbf{D}_x = \mathbf{a}_x H. \end{cases} \tag{7}$$

Thus equipotential surfaces are parallel planes and **D** is the same throughout the field.

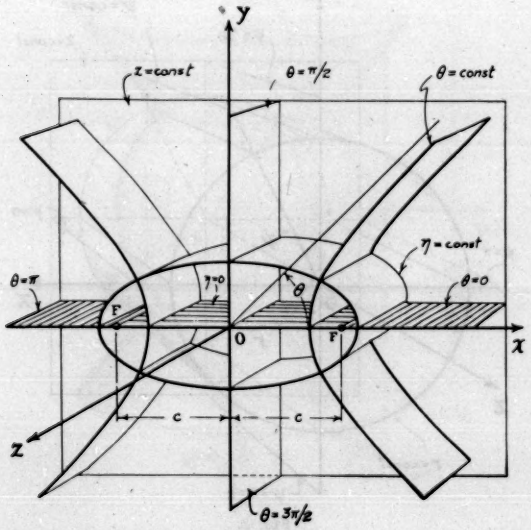

FIG. 3.

Cylindrical Sources

According to Theorem 16, a *circular-cylinder* source of infinite length and uniform helios produces an irrotational field. Borrowing results from electrostatics, we find that

$$\begin{cases} \varphi = Ha \ln (a/r), \\ \mathbf{D} = \mathbf{a}_r H \cdot (a/r), \end{cases} \tag{8}$$

where $\mathbf{a}_r$ is a unit vector from the axis of the cylinder toward the point P, and a is the radius of the cylinder (Fig. 2).

For a uniform *elliptic cylinder* of infinite length, a quasipotential exists (Theorem 21). Elliptic-cylinder (2) coordinates (Fig. 3) are used and Laplace's equation is

$$\frac{d^2\Phi}{d\eta^2} = 0,$$

with solution,

$$\Phi = A + B\eta,$$

$$\nabla\Phi = \frac{\mathbf{a}_\eta B}{c\sqrt{\cosh^2\eta - \cos^2\theta}}. \tag{9}$$

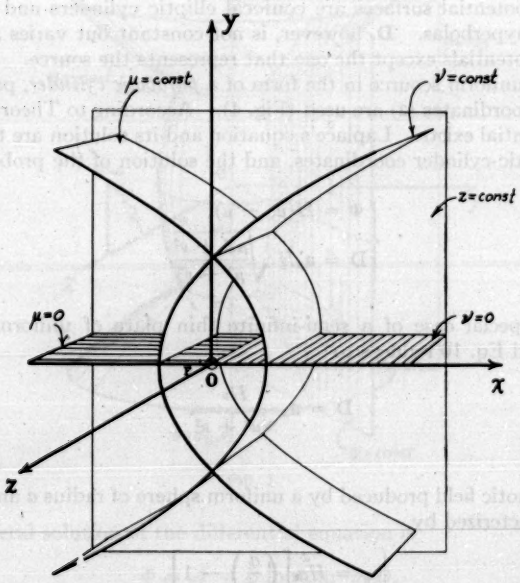

FIG. 4.

Boundary conditions are (Theorem 18):

$$\begin{cases} \text{when } \eta = \eta_0, & \mathbf{D} = \mathbf{a}_\eta H \quad \text{and} \quad \Phi = 0; \\ \text{when } \eta \to \infty, & \mathbf{D} \to 0. \end{cases}$$

Substitution gives $B = -H$, $\zeta = \dfrac{1}{c\sqrt{\cosh^2\eta_0 - \cos^2\theta}}$, so

$$\begin{cases} \Phi = H\cdot(\eta_0 - \eta), \\ \mathbf{D} = \mathbf{a}_\eta H \sqrt{\dfrac{\cosh^2\eta_0 - \cos^2\theta}{\cosh^2\eta - \cos^2\theta}}. \end{cases} \tag{9a}$$

For the special case of an infinite flat strip of width $2c$, $\eta_0 = 0$ and Eq. 9*a* becomes

$$\mathbf{D} = \mathbf{a}_\eta \frac{H \sin\theta}{\sqrt{\cosh^2\eta - \cos^2\theta}}. \tag{9b}$$

The equipotential surfaces are confocal elliptic cylinders and the flux lines are hyperbolas. **D**, however, is not constant but varies along all the equipotentials except the one that represents the source.

For a uniform scource in the form of a *parabolic cylinder*, parabolic-cylinder coordinates (2) are used (Fig. 4). According to Theorem 21, a quasipotential exists. Laplace's equation and its solution are the same as in elliptic-cylinder coordinates, and the solution of the problem is

$$\begin{cases} \Phi = H(\mu_0 - \mu), \\ \mathbf{D} = \mathbf{a}_\mu H \sqrt{\dfrac{\mu_0^2 + \nu^2}{\mu^2 + \nu^2}}. \end{cases} \tag{10}$$

For the special case of a semi-infinite thin plate of uniform helios, $\mu_0 = 0$ and Eq. 10 reduces to

$$\mathbf{D} = \mathbf{a}_\mu \frac{H\nu}{\sqrt{\mu^2 + \nu^2}}. \tag{10a}$$

Sphere

The photic field produced by a uniform sphere of radius a and helios H is characterized by

$$\begin{cases} \varphi = Ha\left[\left(\dfrac{a}{r}\right) - 1\right], \\ \mathbf{D} = \mathbf{a}_r H\cdot\left(\dfrac{a}{r}\right)^2. \end{cases} \tag{11}$$

Equipotential surfaces are concentric spheres, and **D** is always radial and has a magnitude that depends on r only.

Prolate Spheroid

According to Theorem 22, a quasipotential exists in the photic field produced by a prolate spheroid of uniform helios. Prolate spheroidal coordinates (η, θ, ψ) will be employed (Fig. 5), and Laplace's equation is

$$\frac{d^2\Phi}{d\eta^2} + \coth\eta \frac{d\Phi}{d\eta} = 0.$$

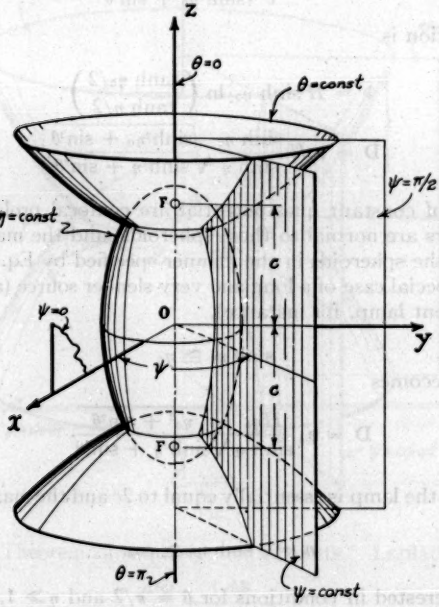

FIG. 5.

The general solution of the differential equation is

$$\Phi = A + B \ln \tanh (\eta/2),$$

and

$$\nabla\Phi = \frac{\mathbf{a}_\eta}{c\sqrt{\sinh^2\eta + \sin^2\theta}} \frac{d\Phi}{d\eta}$$

$$= \frac{\mathbf{a}_\eta B}{c \sinh \eta \sqrt{\sinh^2\eta + \sin^2\theta}}.$$

Boundary conditions are (by Theorem 18):

$$\begin{cases} \text{when } \eta = \eta_0, & \mathbf{D} = \mathbf{a}_\eta H \quad \text{and} \quad \Phi = 0; \\ \text{when } \eta \to \infty, & \mathbf{D} \to 0. \end{cases}$$

Substitution shows that

$$\zeta = \frac{1}{c\sqrt{\sinh^2\eta_0 + \sin^2\theta}}$$

and the solution is

$$\begin{cases} \Phi = H \sinh \eta_0 \cdot \ln\left(\dfrac{\tanh \eta_0/2}{\tanh \eta/2}\right), \\ \mathbf{D} = \mathbf{a}_\eta H \dfrac{\sinh \eta_0}{\sinh \eta}\sqrt{\dfrac{\sinh^2\eta_0 + \sin^2\theta}{\sinh^2\eta + \sin^2\theta}}. \end{cases} \tag{12}$$

Surfaces of constant quasipotential are confocal prolate spheroids. The **D**-vectors are normal to these spheroids, and the magnitude of **D** varies along the spheroids in the manner specified by Eq. 12.

For the special case of a long and very slender source (approximated by a fluorescent lamp, for instance),

$$\sinh \eta_0 \cong \eta_0$$

and Eq. 12 becomes

$$\mathbf{D} = \mathbf{a}_\eta \frac{H\eta_0}{\sinh \eta}\sqrt{\frac{\eta_0^2 + \sin^2\theta}{\sinh^2\eta + \sin^2\theta}}. \tag{12a}$$

The length of the lamp is essentially equal to $2c$ and the maximum radius is

$$a = c \sinh \eta_0 \cong c\eta_0.$$

If we are interested in conditions for $\theta = \pi/2$ and $\eta \gg 1$, the distance from the lamp is

$$x = c \sinh \eta \cong c \cosh \eta$$

and Eq. 12*a* reduces to the simple formula,

$$D = \frac{Hac}{x^2}.$$

The oblate spheroid is treated in a similar manner. It and its degenerate case, the circular-disk source, were considered in the previous paper (1).

Paraboloid

In treating the paraboloidal source of uniform helios, we use parabolic coordinates (Fig. 6). The source is a paraboloid of revolution; so,

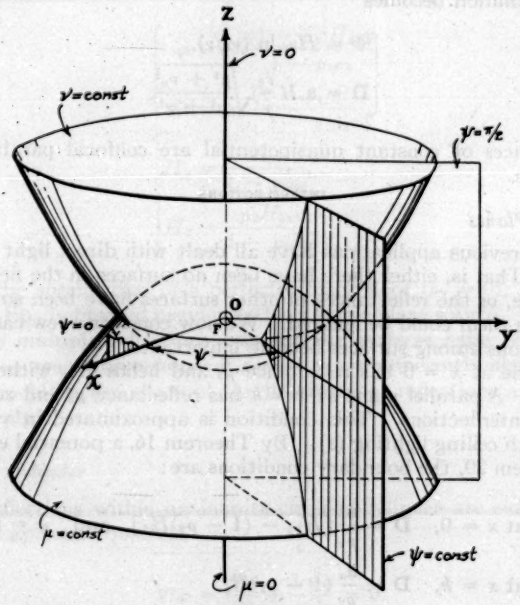

FIG. 6.

according to Theorem 22, a quasipotential exists. Laplace's equation is

$$\frac{d^2\Phi}{d\nu^2} + \frac{1}{\nu}\frac{d\Phi}{d\nu} = 0,$$

whose solution is

$$\Phi = A + B \ln \nu.$$

Also,

$$\nabla\Phi = \frac{\mathbf{a}_\nu}{\sqrt{\mu^2 + \nu^2}}\frac{d\Phi}{d\nu}$$

$$= \frac{\mathbf{a}_\nu B}{\nu\sqrt{\mu^2 + \nu^2}}.$$

On the source, $\nu = \nu_0$ and

$$\mathbf{D} = \mathbf{a}_\nu H, \quad \Phi = 0.$$

Let

$$\zeta = \frac{1}{\sqrt{\mu_0^2 + \nu^2}}$$

and the solution becomes

$$\begin{cases} \Phi = H\nu_0 \ln(\nu_0/\nu), \\ \mathbf{D} = \mathbf{a}_x H \dfrac{\nu_0}{\nu} \sqrt{\dfrac{\mu^2 + \nu_0^2}{\mu^2 + \nu^2}}. \end{cases} \tag{13}$$

The surfaces of constant quasipotential are confocal paraboloids of revolution.

INTERFLECTIONS

Parallel Planes

The previous applications have all dealt with direct light from the source. That is, either there have been no surfaces in the field except the source, or the reflectances of other surfaces have been so low that light from them could be ignored. We now consider a few cases where interflections among surfaces become important.

A plane at $x = 0$ has reflectance ρ_2 and helios H_{02} without interflections. A parallel plane at $x = h$ has reflectance ρ_3 and zero helios without interflections. This condition is approximated in very large rooms with ceiling lighting (3). By Theorem 16, a potential exists and by Theorem 20, the boundary conditions are:

$$\begin{cases} \text{at } x = 0, \quad \mathbf{D} = \dfrac{\mathbf{a}_x}{\rho_2}[H_{02} - (1 - \rho_2)H_2] \quad \text{and} \quad \varphi = 0; \\ \text{at } x = h, \quad \mathbf{D} = \dfrac{\mathbf{a}_x}{\rho_3}(1 - \rho_3)H_3. \end{cases}$$

Here H_2 and H_3 are the true values of helios, including all interflections.

According to Theorem 6, Laplace's equation holds:

$$\nabla^2\varphi = \frac{d^2\varphi}{dx^2} = 0.$$

The general solution is

$$\varphi = A + Bx$$

and the pharosage vector is

$$\mathbf{D} = -\nabla\varphi = -\mathbf{a}_x B.$$

Substitution of the boundary conditions shows that $A = 0$ and

$$B = -\frac{(1 - \rho_3)}{\rho_3} H_3 = \frac{(1 - \rho_2)}{\rho_2} H_2 - \frac{H_{02}}{\rho_2},$$

and use of the photometric relation

$$H_3 = \rho_3 H_2$$

leads to the solution

$$\begin{cases} \varphi = -\dfrac{(1-\rho_3)H_{02}x}{1-\rho_2\rho_3}, \\ \mathbf{D} = \mathbf{a}_x \dfrac{(1-\rho_3)H_{02}}{1-\rho_2\rho_3}, \\ H_2 = \dfrac{H_{02}}{1-\rho_2\rho_3}, \\ H_3 = \dfrac{\rho_3 H_{02}}{1-\rho_2\rho_3}. \end{cases} \tag{14}$$

For the special case of a perfectly black floor ($\rho_3 = 0$), Eq. 14 reduces to Eq. 7 obtained previously for a single plane source. If $\rho_3 \neq 0$, however, multiple reflections between the surfaces raise H_2 and H_3, which may reach large values if ρ_2 and ρ_3 are sufficiently high. Equation 14, includes the effect of the infinitude of reflections and does it very simply.

Circular Cylinder

Interflections within an infinite circular cylinder are evaluated by solving Laplace's equation,

$$\nabla^2\varphi = \frac{d^2\varphi}{dr^2} + \frac{1}{r}\frac{d\varphi}{dr} = 0.$$

The general solution is

$$\varphi = A + B \ln r,$$

subject to the boundary conditions,

$$\begin{cases} \mathbf{D} = -\dfrac{\mathbf{a}_r}{\rho}[H_0 - (1-\rho)H] \text{ at } r = a; \\ \varphi = 0 \text{ at } r = 0. \end{cases}$$

To keep the potential finite at $r = 0$, we must make $B = 0$. Also,

$$\mathbf{D} = -\nabla\varphi = -\mathbf{a}_r \frac{d\varphi}{dr} = 0,$$

so $A = 0$. Thus the solution is

$$\begin{cases} \varphi = 0, \\ \mathbf{D} = 0, \\ H = \dfrac{H_0}{1 - \rho}. \end{cases} \tag{15}$$

The pharosage vector is everywhere zero, which means that as much energy is flowing in one direction as in another. In other words, the cylinder is acting as a *Hohlraum* or blackbody. The equation for helios shows that the brightness of the walls rises rapidly as the reflectance increases.

Next consider two concentric cylinders of infinite length and with radii a and b ($b > a$). This condition might be approximated in practice by a long fluorescent lamp enclosed in a tube of diffusing plastic. Boundary conditions are, according to Theorem 20:

$$\begin{cases} \text{when } r = a, \quad \mathbf{D} = \dfrac{\mathbf{a}_r}{\rho_1}[H_{01} - (1 - \rho_1)H_1] \text{ and } \varphi = 0; \\ \text{when } r = b, \quad \mathbf{D} = \dfrac{\mathbf{a}_r}{\rho_2}(1 - \rho_2)H_2. \end{cases}$$

Solution of Laplace's equation is again

$$\varphi = A + B \ln r$$

and

$$\mathbf{D} = -\mathbf{a}_r \frac{B}{r}.$$

Used in conjunction with the relation

$$H_1 = H_{01} + \rho_1 H_2,$$

which is obvious by the unit-sphere method (4), we obtain the solution,

$$\begin{cases} \varphi = \dfrac{-ab(1 - \rho_2)H_{01}}{a\rho_2(1 - \rho_1) + b(1 - \rho_2)} \ln (r/a), \\ \mathbf{D} = \mathbf{a}_r \dfrac{ab(1 - \rho_2)H_{01}}{r[a\rho_2(1 - \rho_1) + b(1 - \rho_2)]}, \\ H_1 = \dfrac{a\rho_2 + b(1 - \rho_2)}{a\rho_2(1 - \rho_1) + b(1 - \rho_2)} H_{01}, \\ H_2 = \dfrac{a\rho_2 H_{01}}{a\rho_2(1 - \rho_1) + b(1 - \rho_2)}. \end{cases} \tag{16}$$

Sphere

For interflections in spheres, the procedure is the same as for circular cylinders, the only difference being that spherical coordinates are used instead of cylindrical. Laplace's equation is

$$\nabla^2\varphi = \frac{d^2\varphi}{dr^2} + \frac{2}{r}\frac{d\varphi}{dr} = 0$$

and its general solution for the uniform spherical source is

$$\varphi = A + B/r.$$

For a single sphere, φ must be finite at the center, so $B = 0$. The boundary condition, according to Theorem 20, is

$$\mathbf{D} = \frac{-\mathbf{a}_r}{\rho}[H_0 - (1-\rho)H] \text{ at } r = a.$$

Thus the solution is

$$\begin{cases} \varphi = 0, \\ \mathbf{D} = 0, \\ H = \dfrac{H_0}{1-\rho}. \end{cases} \tag{17}$$

For two concentric spheres with radii a and b $(b > a)$, the inside one being self-luminous, the boundary conditions are

$$\begin{cases} r = a, \quad \mathbf{D} = \dfrac{\mathbf{a}_r}{\rho_1}[H_{01} - (1-\rho_1)H_1], \quad \text{and } \varphi = 0; \\ r = b, \quad \mathbf{D} = \dfrac{\mathbf{a}_r}{\rho_2}(1-\rho_2)H_2. \end{cases}$$

Also, from elementary photometrics,

$$H_1 = H_{01} + \rho_1 H_2.$$

Therefore,

$$\begin{cases} \varphi = \dfrac{-ab^2(r-a)(1-\rho_2)H_{01}}{r[a^2\rho_2(1-\rho_1) + b^2(1-\rho_2)]}, \\ \mathbf{D} = \mathbf{a}_r \dfrac{a^2b^2(1-\rho_2)H_{01}}{r^2[a^2\rho_2(1-\rho_1) + b^2(1-\rho_2)]}, \\ H_1 = \dfrac{a^2\rho_2 + b^2(1-\rho_2)}{a^2\rho_2(1-\rho_1) + b^2(1-\rho_2)} H_{01}, \\ H_2 = \dfrac{a^2\rho_2 H_{01}}{a^2\rho_2(1-\rho_1) + b^2(1-\rho_2)}. \end{cases} \tag{18}$$

SUMMARY

The paper continues the discussion of the photic field ("light field," "illumination field," "radiation field") begun in an earlier paper (1). The theorems developed previously are now applied to a number of examples which may be classified as (*a*) elementary (point) sources, (*b*) surface sources (no interflections), or (*c*) surface sources with interflections.

The method consists in an application of ordinary potential theory (such as used in electrostatics) to problems in radiation and light. In a few cases, a scalar potential exists and the problem is identical mathematically with the corresponding electrostatic problem. In most photic fields, however, a scalar potential does not exist but a quasipotential may be used. It is the use of this quasipotential that constitutes the principal novelty in the treatment given in our two papers. In cases where a quasipotential exists and the integration factor can be found, photic field theory provides a simple and elegant method of obtaining the distribution of radiant energy from a light source.

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PARRY MOON AND D. E. SPENCER, "Cylindrical and Rotational Coordinate Systems," JOUR. FRANKLIN INST., Vol. 252, p. 327–344 (1951).

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(4) PARRY MOON, "Scientific Basis of Illuminating Engineering," New York, McGraw-Hill Book Co., 1936, p. 294.

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POWERLESS GLIDES ALONG ZERO CURVATURE FLIGHT PATHS

BY

VICTOR W. BOLIE[1]

I. INTRODUCTION

This paper is concerned with powerless glides along zero curvature flight paths. Equations are derived to give the time variations of airspeed, angle of attack, pitch angle, and air distance. The angle σ of inclination of the flight path from the horizontal may be either positive, negative, or zero, corresponding to an ascending, descending, or horizontal glide.

The simplifying assumptions are that the coefficients C_L and C_D of lift and drag, respectively, are each linear functions of the angle of attack α. While C_L is nearly a linear function of α, the coefficient C_D of drag is more nearly a quadratic.[2] Hence, the speed range for which the results are valid is contingent upon the agreement of the actual values of C_L and C_D with their linear approximations. However, an example is used to show that the predicted results agree with the experimental results throughout a considerable speed range.

The results obtained may find application in emergency procedures following power failure after take-off, post-mortem investigations of air crashes, remotely controlled missiles, automatic approaches by glide path, and other glide problems. The results are not valid in the neighborhood of stalling speed because of the severe non-linearity of the lift and drag coefficients in the vicinity of stalling speed.

The constants which appear in the airspeed and distance formulas can be evaluated for a particular airplane by making only two constant-rate-of-descent glides, each at a different airspeed. The other constants which appear in the expressions for pitch angle and angle of attack can be evaluated if the angle of attack for straight and level flight at a fixed airspeed is known.

II. EQUATIONS OF MOTION

Consider an aircraft moving along a flight path of curvature K in the xy-plane as in Fig. 1. The flight path makes an angle $\sigma = \theta - \alpha$ with the horizontal if θ is the pitch angle and α is the angle of attack. The thrust axis is assumed parallel to the zero-lift chord. This assumption, if not satisfied exactly in practice, is of no consequence in the results

[1] Scientific Staff, Collins Radio Company, Cedar Rapids, Iowa.

[2] Reference: Richard Von Mises, "Theory of Flight," New York, McGraw-Hill Book Co., Inc., 1945.

derived for powerless glides. The lift L, drag D, weight W, thrust T, and velocity V are represented as vectors in Fig. 1.

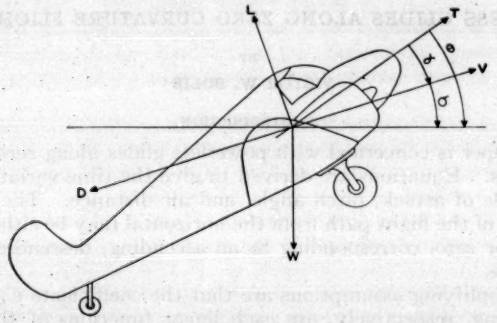

FIG. 1.

By resolving the forces normal and tangent to the flight path, the equations of motion may be written as

$$m\dot{v} = T\cos\alpha - D - W\sin\sigma \tag{1}$$

$$mv^2K = L + T\sin\alpha - W\cos\sigma, \tag{2}$$

where the dot indicates a derivative with respect to time t and K is the curvature of the flight path. The curvature K may be written

$$K = \frac{d\sigma}{ds} = \frac{dt}{ds}\frac{d\sigma}{dt} = \frac{\dot{\sigma}}{v}. \tag{3}$$

It will be assumed, as previously mentioned, that the lift L and drag D, for a particular aircraft and air density, may be represented as linear functions of α, namely,

$$L = k_L\alpha v^2 \tag{4}$$

$$D = (D_0 + k_D\alpha)v^2, \tag{5}$$

where k_L, k_D, and D_0 are constants. These equations follow the assumption that C_L and C_D are linear functions of α.

Equations 3, 4, and 5 may be substituted into (1) and (2) to give

$$m\dot{v} = T\cos\alpha - (D_0 + k_D\alpha)v^2 - mg\sin\sigma \tag{6}$$

$$mv\dot{\sigma} = k_L\alpha v^2 + T\sin\alpha - mg\cos\sigma. \tag{7}$$

For a powerless glide along a zero curvature flight path the above equations become

$$m\dot{v} = -D_0v^2 - k_D\alpha v^2 - mg\sin\sigma \tag{8}$$

$$0 = k_L\alpha v^2 - mg\cos\sigma. \tag{9}$$

The substitution of (9) into (8) gives

$$m\dot{v} = -D_0 v^2 - \frac{mg}{k_L}[k_D \cos\sigma + k_L \sin\sigma]. \tag{10}$$

By using

$$\gamma = \tan^{-1}\frac{k_D}{k_L} \tag{11}$$

and

$$\beta = \sigma + \gamma, \tag{12}$$

Eq. 10 may be written

$$m\dot{v} = -D_0 v^2 - mg\frac{\sin\beta}{\cos\gamma}. \tag{13}$$

The separation of variables in (13) gives the differential equation,

$$\frac{dv}{v^2 + \dfrac{W\sin\beta}{D_0\cos\gamma}} = -\frac{gD_0}{W}dt. \tag{14}$$

The solutions of (14) depend upon the initial velocity v_0 and the angle β. By introducing the notations

$$a = \frac{gD_0}{W} \tag{15}$$

$$b = \sqrt{\left|\frac{W\sin\beta}{D_0\cos\gamma}\right|}, \tag{16}$$

the solutions of (14) may be written

$$v(t) = b\tanh\left(abt + \tanh^{-1}\frac{v_0}{b}\right) \quad \text{if } \beta < 0 \text{ and } v_0 < b \tag{17}$$

$$= b = \text{constant} \quad \text{if } \beta < 0 \text{ and } v_0 = b \tag{18}$$

$$= b\coth\left(abt + \coth^{-1}\frac{v_0}{b}\right) \quad \text{if } \beta < 0 \text{ and } v_0 > b \tag{19}$$

$$= \frac{v_0}{1 + av_0 t} \quad \text{if } \beta = 0 \tag{20}$$

$$= b\cot\left(abt + \cot^{-1}\frac{v_0}{b}\right) \quad \text{if } \beta > 0. \tag{21}$$

The essential properties of Eqs. 17, 18, 19, 20, and 21 are illustrated in Fig. 2.

It is noted in Eq. 19 that $v \to b$ as $t \to \infty$, since $\lim_{q\to\infty} \coth q = 1$.

For this case the airspeed tends to decrease from v_0 to b. It is obvious that if $b < v_s$ then the solution (19) is valid only until the stalling speed v_s is attained. Likewise, Eqs. 20 and 21 are valid only until the stalling speed is attained.

The expressions for the angle of attack α corresponding to Eqs. 17, 18, 19, 20, and 21 are found with the aid of Eq. 9.

$$\alpha(t) = \frac{W\cos\sigma}{k_L b^2}\coth^2\left(abt + \tanh^{-1}\frac{v_0}{b}\right) \quad \text{if } \beta < 0 \text{ and } v_0 < b \tag{22}$$

$$= \frac{W\cos\sigma}{k_L b^2} = \text{constant} \quad \text{if } \beta < 0 \text{ and } v_0 = b \tag{23}$$

$$= \frac{W\cos\sigma}{k_L b^2}\tanh^2\left(abt + \tanh^{-1}\frac{v_0}{b}\right) \quad \text{if } \beta < 0 \text{ and } v_0 > b \tag{24}$$

$$= \frac{W\cos\sigma}{k_L v_0^2}(1 + av_0 t)^2 \quad \text{if } \beta = 0 \tag{25}$$

$$= \frac{W\cos\sigma}{k_L b^2}\tan^2\left(abt + \cot^{-1}\frac{v_0}{b}\right) \quad \text{if } \beta > 0. \tag{26}$$

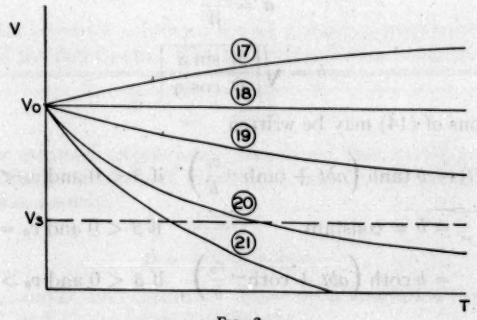

FIG. 2.

The expressions for the pitch angle θ which correspond to the above equations are readily availabe, since $\theta = \sigma + \alpha$. It is noted in Fig. 1 that the θ reference has been taken parallel to the zero lift chord. Since θ is merely the algebraic sum of the glide angle σ and the angle of attack α, the equations for pitch angle will not be written here.

The equations for air distance $s(t)$ which correspond to Eqs. 17, 18, 19, 20, and 21 are found by integrating the latter equations with respect

to time. If $s(o) = 0$, then

$$s(t) = \frac{1}{a} \ln \left[\frac{\sqrt{b^2+v_0^2}}{b} \cosh \left(abt + \tanh^{-1} \frac{v_0}{b} \right) \right] \quad \text{if } \beta<0 \text{ and } v_0<b \quad (27)$$

$$= bt = v_0 t \quad \text{if } \beta<0 \text{ and } v_0=b \quad (28)$$

$$= \frac{1}{a} \ln \left[\frac{\sqrt{v_0^2-b^2}}{b} \sinh \left(abt + \coth^{-1} \frac{v_0}{b} \right) \right] \quad \text{if } \beta<0 \text{ and } v_0>b \quad (29)$$

$$= \frac{1}{a} \ln (1 + av_0 t) \quad \text{if } \beta = 0 \quad (30)$$

$$= \frac{1}{a} \ln \left[\frac{\sqrt{v_0^2+b^2}}{b} \sin \left(abt + \cot^{-1} \frac{v_0}{b} \right) \right] \quad \text{if } \beta>0. \quad (31)$$

The horizontal air distance $x(t)$ and the vertical air distance $y(t)$ covered during the glide are found from the equations, $x = s \cos \sigma$ and $y = s \sin \sigma$.

III. CONCLUSION

The expressions for $v(t)$ and $s(t)$ are given in terms of the constants a and b. The evaluation of these constants requires the knowledge of $\frac{D_0}{W}$ and γ, the latter constants being characteristics of the aircraft.

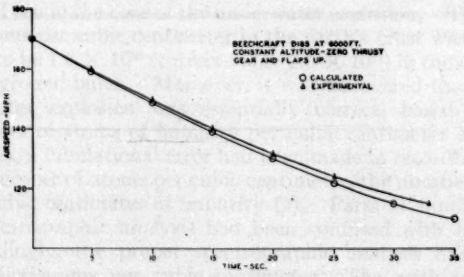

FIG. 3.

These characteristic constants may be found with the aid of Eqs. 16 and 18 by making two constant-rate-of-descent glides, each at a different airspeed. The glide angles σ_1 and σ_2 corresponding to the airspeeds v_1 and v_2 are readily obtained if the associated vertical speeds are recorded. It can be shown that if σ_1 and σ_2 are the glide angles (both are negative) corresponding to the steady airspeeds v_1 and v_2, then the

characteristic constants $\frac{D_0}{W}$ and γ for the particular aircraft are given by

$$\frac{D_0}{W} = \frac{\sin(\sigma_1 - \sigma_2)}{v_1^2 \cos\sigma_2 - v_2^2 \cos\sigma_1} \tag{32}$$

$$\tan\gamma = \frac{v_1^2 \sin\sigma_2 - v_2^2 \sin\sigma_1}{v_2^2 \cos\sigma_1 - v_1^2 \cos\sigma_2}. \tag{33}$$

Equation 21 was verified experimentally by executing a horizontal glide with the Beechcraft D18S at 6000 ft. With the wheels and flaps up, the power was cut and the altitude was maintained by gradually increasing the angle of attack as the airspeed decreased from 170 to 110 mph. The airspeed was recorded at 5-second intervals for 35 seconds. Following this were two steadily descending, power-off glides from which data were obtained to evaluate the required constants. One glide at 110 mph. gave 550 ft. per minute descent while the other at 140 mph. gave 1000 ft. per minute descent. The constants were found to be such that $\frac{D_0}{W} = 1.49 \times 10^{-4}$ and $\tan\gamma = 0.018$. These constants were used in Eq. 21 to find theoretical values of $v(t)$ at 5-second intervals. The theoretical and experimental curves are shown in Fig. 3. The difference between the predicted and actual results was small in this particular test.

SLOW NEUTRON INDUCED RADIOACTIVITIES OF NUCLEAR EXPLOSIONS: III

BY

C. E. MANDEVILLE[1]

In two previous discussions (1, 2),[2] results were presented concerning the slow neutron induced radioactivities to be expected when a gram-molecule of neutrons is liberated in a nuclear explosion. The primary purpose of the calculations was to obtain the order of magnitude of the slow neutron induced radioactivities relative to the total activity of the fission fragments. From correspondence received, it has become evident that the use of the calculated data has been extended beyond the scope of its initial intention. Rather than the order of magnitude of the over-all activity, the contribution of certain specific radioisotopes has become of interest under certain conditions. Suggestions have also been received that the data be placed in more convenient form. In particular, the induced radioactivity of an underwater explosion has been calculated for an elemental impurity of one microgram per cubic centimeter throughout the infinite medium, the activity for each element having been summed over all isotopes.

Several mistakes of an arithmetical nature occurred in the earlier tables of data. For example, the activity of Na^{24} was underestimated by a factor of ten in the case of the underwater explosion. The number of silicon atoms per cubic centimeter in the earth's crust was inadvertently taken to be 1.6×10^{23} (correct value 1.6×10^{22}) in the calculation of the underground burst. Moreover, it was discovered that although the underwater explosion was essentially correct, based upon the quoted number of atoms of impurity per cubic centimeter as given in *Nucleonics* (1), a tabulational error had been made in recording in addition to the number of atoms per cubic centimeter, the number of micrograms per cubic centimeter of impurity (2). Parts of another and irrelevant spectrographic analysis had been confused with the correct one. Accordingly, the proper spectrographic analysis has been recorded in micrograms per cubic centimeter. The arithmetic errors have been removed, and all tables have been recalculated.[3] The magnitudes of the activities are essentially the same as previously reported.

[1] Bartol Research Foundation of The Franklin Institute, Swarthmore, Pa.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

[3] Most of the arithmetical errors were called to the attention of the writer by Dr. Conrad P. Straub, U. S. Public Health Service, Oak Ridge National Laboratory, Oak Ridge, Tenn. Most of the data in the present tables have been checked by Dr. Straub. At the instance of Dr. Straub, the tables were extended to include time intervals of one month, one year, and ten years.

TABLE I.—*Underwater Burst.*

Impurity	Micrograms per cc.	atoms/cc n′	½ life	σ′ (barns)	n′ σ′	Activity in curies		
						at $t=0$	at $t=1$ hr.	at $t=1$ day
Al^{28}	0.31	6.9×10^{15}	2.4 m	0.21	1.4×10^{-9}	5.4×10^{3}	1.7×10^{-4}	—
Ba^{131}	0.1	4.4×10^{14}	12 d	2.4×10^{-5}	1.1×10^{-11}	5.9×10^{-6}	5.9×10^{-6}	5.6×10^{-6}
Ba^{133}			20 y	0.058	2.6×10^{-11}	2.3×10^{-5}	2.3×10^{-5}	2.3×10^{-5}
Ba^{135m}			38 h	0.058	2.6×10^{-11}	1.1×10^{-1}	1.1×10^{-1}	7.1×10^{-2}
Ba^{135m}			28.7 h	0.19	8.4×10^{-11}	4.6×10^{-1}	4.5×10^{-1}	2.6×10^{-1}
Ba^{137m}			2.63 m	0.60	2.6×10^{-10}	9.2×10^{2}	1.6×10^{-4}	—
Ba^{139}			84 m	0.35	1.5×10^{-10}	1.7×10^{1}	1.0×10^{1}	1.5×10^{-4}
B^{12}	0.02	1.1×10^{15}	0.027 s	0.04	4.4×10^{-11}	9.1×10^{3}	—	—
Cu^{64}	0.12	1.1×10^{15}	12.8 h	2	2.2×10^{-9}	2.7×10^{1}	2.6×10^{1}	7.4×10^{0}
Cu^{66}			5 m	0.56	5.6×10^{-10}	1.1×10^{3}	2.6×10^{-1}	—
Cr^{51}	0.01	1.2×10^{14}	26.5 d	0.50	6.0×10^{-11}	1.5×10^{-2}	1.5×10^{-2}	1.5×10^{-2}
Cr^{55}			1.3 h	1.4×10^{-4}	1.7×10^{-14}	2.0×10^{-2}	1.2×10^{-2}	7.1×10^{-9}
F^{20}	0.01	3.2×10^{14}	10.4 s	9.4×10^{-9}	3.0×10^{-12}	1.6×10^{3}	—	—
Pb^{209}	0.02	5.8×10^{15}	3.32 h	0.5	2.9×10^{-11}	1.4×10^{6}	1.1×10^{6}	9.4×10^{-3}
Ni^{59}	0.0016	1.6×10^{13}	2×10^{5} y	2.9	4.6×10^{-11}	4.1×10^{-9}	4.1×10^{-9}	4.1×10^{-9}
Ni^{63}			85 y	0.44	7.0×10^{-12}	1.5×10^{-6}	1.5×10^{-6}	1.5×10^{-6}
Ni^{65}			2.6 h	1.7×10^{-2}	2.7×10^{-13}	1.6×10^{-2}	1.2×10^{-2}	2.7×10^{-5}
Mn^{56}	0.055	6.0×10^{14}	2.59 h	10.7	6.4×10^{-9}	3.8×10^{3}	2.9×10^{3}	6.2×10^{-1}
K^{42}	0.01	1.5×10^{14}	12.4 h	6.7×10^{-3}	1.0×10^{-11}	1.3×10^{-1}	1.2×10^{-1}	3.4×10^{-3}
Na^{24}	10	2.6×10^{17}	15 h	0.63	1.6×10^{-7}	1.7×10^{3}	1.6×10^{3}	5.6×10^{2}
Ag^{108}	0.0054	3.0×10^{13}	2.3 m	23	6.9×10^{-10}	2.8×10^{3}	4.0×10^{-5}	—
Ag^{110m}			22 s	46.6	1.4×10^{-9}	3.6×10^{4}	—	—
Ag^{110}			225 d	1.1	3.3×10^{-11}	9.5×10^{-4}	9.5×10^{-4}	9.5×10^{-4}
Sr^{87m}	0.25	1.7×10^{15}	2.7 h	0.128	2.2×10^{-10}	1.3×10^{1}	1.0×10^{1}	2.7×10^{-2}
Sr^{89}			55 d	4×10^{-2}	6.8×10^{-13}	8.0×10^{-4}	8.0×10^{-4}	7.9×10^{-4}
Sn^{113}	0.002	1.0×10^{13}	105 d	0.012	1.2×10^{-13}	7.4×10^{-8}	7.4×10^{-8}	7.4×10^{-8}
Sn^{125m}			9 m	0.039	3.9×10^{-13}	4.0×10^{-1}	3.9×10^{-1}	—
Sn^{125}			10 d	0.009	9.0×10^{-14}	5.8×10^{-5}	5.8×10^{-5}	5.4×10^{-5}
Sn?			40 m	0.014	1.4×10^{-13}	3.3×10^{-2}	1.2×10^{-2}	—
Sn?			26 h	0.072	7.2×10^{-13}	4.3×10^{-3}	4.2×10^{-3}	2.3×10^{-3}
Sn?			400 d	0.018	1.8×10^{-13}	2.9×10^{-8}	2.9×10^{-8}	2.9×10^{-8}
Zn^{65}	0.0054	5.0×10^{13}	250 d	0.26	1.3×10^{-11}	3.4×10^{-4}	3.4×10^{-4}	3.4×10^{-4}
Zn^{69}			13.8 h	0.054	2.7×10^{-12}	3.0×10^{-3}	2.8×10^{-3}	9.0×10^{-3}
Zn^{69m}			57 m	0.19	9.5×10^{-13}	1.5×10^{0}	7.2×10^{-1}	—
V^{52}	0.0033	3.9×10^{13}	3.9 m	4.5	1.8×10^{-10}	4.3×10^{3}	1.0×10^{-2}	—
Sb^{122}	0.006	3.0×10^{13}	2.8 d	3.1	9.3×10^{-11}	2.2×10^{-1}	2.2×10^{-1}	1.7×10^{-1}
Sb^{124}			60 d	1.1	3.3×10^{-11}	3.6×10^{-3}	3.6×10^{-3}	3.6×10^{-3}
Mo^{99}	Trace	1.0×10^{13}	67 h	0.10	1.0×10^{-12}	2.3×10^{-4}	2.3×10^{-4}	1.8×10^{-4}
Mo^{101}			19 m	0.044	4.4×10^{-14}	2.2×10^{-2}	3.1×10^{-2}	—
Mo?			7 h	0.001	1.0×10^{-13}	2.2×10^{-5}	2.0×10^{-5}	2.0×10^{-5}
O^{19}		3.3×10^{20}	31 s	4×10^{-7}	1.3×10^{-6}	2.3×10^{4}	—	—
Totals						1.2×10^{6}	1.9×10^{6}	5.7×10^{3}

Totals		
	1 week	7.9×10^{-1} curies
	1 month	1.1×10^{0} curies
	1 year	1.0×10^{-2} curies
	10 years	1.7×10^{-2} curies

TABLE II.—*Underground Blast.*

Radio-element	gms/cc target material	No. of atoms/cc	Half-life	Cross section isotope prod.	Total cross section	Activity in curies		
						$t=0$	$t=1$ hr.	$t=1$ day
O^{19}	1.24	4.7×10^{22}	31 s	4×10^{-7}	9×10^{-4}	5.0×10^{5}	—	—
Si^{31}	0.74	1.6×10^{22}	170 m	4.9×10^{-3}	0.135	6.2×10^{8}	4.9×10^{8}	1.8×10^{4}
Al^{28}	0.21	4.7×10^{21}	2.4 m	0.21	0.21	5.6×10^{9}	1.7×10^{3}	—
Fe^{59}	0.13	1.4×10^{21}	46.3 d	1×10^{-3}	2.425	2.9×10^{2}	2.9×10^{2}	2.9×10^{2}
Ca^{45} Ca^{49} Ca^{49m}	0.10	1.5×10^{21}	152 d 2.5 h 30 m	0.013 3.9×10^{-4} 1×10^{-3}	0.42	1.2×10^{2} 5.2×10^{4} 6.8×10^{5}	1.2×10^{2} 3.9×10^{4} 1.7×10^{5}	1.2×10^{2} 6.7×10^{1} 2.5×10^{-9}
Na^{24}	0.075	2.0×10^{21}	15 h	0.63	0.63	2.0×10^{7}	1.9×10^{7}	6.6×10^{6}
K^{42}	0.07	1.1×10^{21}	12.4 h	0.067	2.05	1.3×10^{8}	1.2×10^{8}	3.4×10^{5}
Mg^{27}	0.06	1.5×10^{21}	10.2 m	5.4×10^{-3}	0.06	1.1×10^{7}	1.9×10^{3}	—
Ti^{51}	0.02	2.5×10^{20}	6 m	7.5×10^{-2}	5.85	4.3×10^{8}	4.2×10^{3}	—
P^{32}	0.003	5.8×10^{19}	14.3 d	0.23	0.23	8.6×10^{3}	8.6×10^{3}	8.2×10^{3}
Mn^{56}	0.002	2.2×10^{19}	2.6 h	10.7	10.7	2.0×10^{7}	1.5×10^{7}	3.3×10^{5}
F^{20}	0.002	6.3×10^{19}	10.4 s	9.4×10^{-3}	9.4×10^{-3}	4.7×10^{7}	—	—
Cl^{38} Cl^{38}	0.001	1.7×10^{19}	2×10^{4} y 38.5 m	31.9 0.137	32	7.1×10^{-2} 8.1×10^{5}	7.1×10^{-2} 2.8×10^{5}	7.1×10^{-2} 4.9×10^{-6}
S^{35} S^{37}	0.001	1.9×10^{19}	87.1 d 5.0 m	0.011 1.4×10^{-4}	0.5	2.3×10^{1} 7.5×10^{3}	2.3×10^{1} 1.9×10^{-1}	2.3×10^{1} —
Ba^{131} Ba^{133} Ba^{133m} Ba^{135m} Ba^{137m} Ba^{139}	0.001	4.4×10^{18}	12 d 20 y 38 h 28.7 h 2.63 m 84 m	2.4×10^{-5} 0.058 0.058 0.19 0.60 0.35	1.10	8.7×10^{-2} 3.3×10^{-1} 1.5×10^{3} 6.7×10^{3} 1.3×10^{7} 2.4×10^{4}	8.7×10^{-2} 3.3×10^{-1} 1.5×10^{3} 6.5×10^{3} 1.8×10^{6} 1.5×10^{4}	8.2×10^{-2} 3.3×10^{-1} 9.7×10^{2} 3.7×10^{3} — 1.7×10^{3}
C^{14}	0.0007	3.5×10^{19}	5,100 y	1×10^{-3}	4.7×10^{-2}	1.8×10^{-4}	1.8×10^{-4}	1.8×10^{-4}
Sr^{87m} Sr^{89}	0.0005	3.4×10^{18}	2.7 h 55 d	0.128 4×10^{-3}	1.35	3.7×10^{4} 2.4×10^{3}	2.9×10^{4} 2.4×10^{3}	7.8×10^{1} 2.4×10^{3}
Totals						5.7×10^{8}	4.1×10^{7}	7.0×10^{4}

Totals 1 week 1.7×10^{4} curies
1 month 3.3×10^{3} curies
1 year 2.3×10^{3} curies
10 years 3.0×10^{-1} curies

TABLE III.—*Activity per Microgram*

Element	Al	Ba	B	Cu	Cr	F	Pb	Ni	Mn
Atoms per microgram	2.23 × 10^{16}	4.38 × 10^{15}	5.57 × 10^{16}	9.47 × 10^{15}	1.16 × 10^{16}	3.17 × 10^{16}	2.91 × 10^{15}	1.03 × 10^{16}	1.10 × 10^{16}
Activity per μ g at time zero, curies	1.80 × 10^{4}	9.34 × 10^{3}	4.60 × 10^{7}	9.70 × 10^{3}	1.65	1.58 × 10^{4}	70.3	10.3	6.95 × 10^{3}
Activity at $t=1$ hr. (curies)	5.66 × 10^{-4}	1.05 × 10^{3}	—	226	1.57	—	55.2	7.73	5.31 × 10^{3}
Activity at $t=24$ hrs. (curies)	—	3.30	—	63.7	1.46	—	4.7 × 10^{-1}	1.84 × 10^{-2}	11.35
Activity at $t=1$ wk. (curies)	—	1.63 × 10^{-1}	—	2.6 × 10^{-2}	1.17	—	—	9.66 × 10^{-4}	—
Activity at $t=1$ mo. (curies)	—	2.61 × 10^{-4}	—	—	6.6 × 10^{-1}	—	—	9.66 × 10^{-4}	—
Activity at $t=1$ yr. (curies)	—	2.19 × 10^{-4}	—	—	1.36 × 10^{-4}	—	—	9.66 × 10^{-4}	—
Activity at $t=10$ yrs. (curies)	—	1.60 × 10^{-4}	—	—	—	—	—	9.02 × 10^{-4}	—

per Cubic Centimeter of Impurity.

Element	K	Na	Ag	Sr	Sn	Zn	V	Sb	Mo
Atoms per microgram	1.54 × 10^{18}	2.62 × 10^{18}	5.58 × 10^{15}	6.87 × 10^{15}	5.07 × 10^{15}	9.21 × 10^{15}	1.10 × 10^{16}	4.94 × 10^{15}	6.27 × 10^{15}
Activity per μ g at time zero, curies	13.3	1.70 × 10^{2}	7.22 × 10^{6}	52.5	2.22 × 10^{2}	2.82 × 10^{2}	1.21 × 10^{5}	36.9	1.39 × 10^{2}
Activity at $t=1$ hr. (curies)	12.2	1.60 × 10^{2}	1.84 × 10^{-1}	40.4	10.2	1.38 × 10^{2}	2.82	36.9	21.0
Activity at $t=24$ hrs. (curies)	3.47	56	1.77 × 10^{-1}	1.12 × 10^{-1}	1.20	1.72	—	28.6	1.14
Activity at $t=1$ wk. (curies)	1.12 × 10^{-3}	7.1 × 10^{-3}	1.75 × 10^{-1}	2.98 × 10^{-3}	4.8 × 10^{-3}	6.38 × 10^{-3}	—	6.87	2.5 × 10^{-1}
Activity at $t=1$ mo. (curies)	—	—	1.62 × 10^{-1}	2.25 × 10^{-3}	8.2 × 10^{-3}	5.7 × 10^{-3}	—	0.43	8.03 × 10^{-4}
Activity at $t=1$ yr. (curies)	—	—	4.65 × 10^{-2}	3.26 × 10^{-4}	1.1 × 10^{-3}	2.21 × 10^{-2}	—	8.86 × 10^{-2}	—
Activity at $t=10$ yrs. (curies)	—	—	2.42 × 10^{-6}	—	2.64 × 10^{-6}	2.58 × 10^{-6}	—	—	—

REFERENCES

(1) C. E. MANDEVILLE, *Nucleonics*, Vol. 9, No. 5, p. 8 (1951).

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Multi-Probe Ultra-Viscoson Systems.—The Ultra-Viscoson Corporation, Hartford, Connecticut, announces Model MP Multi-Probe Ultra-Viscoson systems for continuous, automatic viscosity measurement to 650° F., and 1000 psi. pressure at up to 16 probe stations. Hermetically sealed ultrasonic probes the size of a fountain pen, having no moving parts, are installed permanently in up to 16 kettles or pipe lines. One Ultra-Viscoson computer and multiplex unit located up to one mile from probes indicates viscosity measured by any desired probe, or automatically records viscosities singly or in sequence on standard multipoint industrial recorders. Up to 16 kettles, reactors or pipe-lines are monitored automatically in production and application of resins, starch, high polymers, foods, inks, petroleum products, adhesives, gelatin, paints, coatings, paper, textiles and soaps.

Industry Provides Own Fire Protection.—"Car 15 to KKB 241 . . . Line of four fires just been set in section six, one-half mile north Warren Switch . . . Send car 12 and car 8 in from Pilgrim's Rest church . . . Car 15 following man who set fires . . . Will advise . . . Car 15 clear."

That would be a radio message in Central Mississippi, but what the aver age radio monitor might not realize is this: Car 15 is actually a four-place Beechcraft Bonanza airplane. KKB 241 is the control tower in a chain of four fire towers. Cars 12 and 8 are two of 27 mobile units, including trucks, tractors and fire plows, all in constant two-way communication with each other. All this forest fire control equipment is owned and operated, without assistance from the state or federal governments, by the Central Fire Control Association with headquarters in Carthage, Miss. The organization is made up of and financed by individual forest industries and timberland owners in four counties.

Annual membership dues were set up in relationship to size of timber holdings. Free membership is granted to owners of less than 160 acres provided they agree to cooperate in fighting their own fires and those of their neighbors. Owners of 160 to 500 acres pay 2 cents per acre, while all larger owners pay 5 cents per acre.

The detection plane is piloted by John Tyler, a naval aviator during World War II. During critical fire periods he flies the plane over the four-county area several hours each day. In addition to supplying excellent detection facilities, the plane, through its two-way radio contact with mobile units, also directs trucks along best routes to approach a fire. Often the progress of a fire can be better assessed from the air and at various stages the plane can suggest new lines of attack. Use of the plane has even been instrumental in securing the arrest and conviction of incendiarists.

While CFC is operated and financed independently of government assistance, the group cooperates with all who desire it. Cooperative agreements are maintained with the U. S. Forest Service, National Park Service and the Mississippi Forest Service. Cooperation consists chiefly of CFC assistance to adjacent areas.

NOTES FROM THE FRANKLIN INSTITUTE LABORATORIES FOR RESEARCH AND DEVELOPMENT

DEVELOPMENT OF A PRODUCTION CONTROL TEST

A local manufacturer had recently set up a new production line for the manufacture of an improved elastomeric separator for use in storage batteries. It was necessary to develop suitable tests for controlling each step in production operations, and one of the required control tests was developed by The Franklin Institute Laboratories in less than two weeks.

The control problem was to assure that the concentration of wetting agent in one of the production operations would remain between acceptable limits, and, since the test was to be used for control purposes, it had to be quick and easy but not necessarily extremely precise. It was decided that a reasonable approach would be to correlate the strength of the wetting agent with the wetting properties of the solution as measured by a simple test. Three such tests were visualized:

(*a*) The measurement of the time required for a patch of cotton duck floating on the surface to become wet and sink;

(*b*) Measurement of the contact angle of a drop of the solution on paraffin wax; and

(*c*) Measurement of the interfacial tension between the solution and a hydrophobic organic liquid such as kerosene or iso-octane.

Experiments showed that the patch test gave suitable results in the concentration range of 0.1 to 1 per cent wetting agent but was unsatisfactory at the lower concentrations involved in this problem. Several quick tests showed that measurement of contact angles could not handily afford the discrimination required, and hence this approach was also ruled out. It was found, however, that measurements of the interfacial tension between the unknown solution and kerosene could be made quickly with the du Nuoy tensiometer, with a satisfactory reproducibility and with good discrimination between solutions of varying strengths. The method was therefore recommended to the manufacturer, and a tensiometer was loaned to them so that they could immediately start using it. The company reports that the method appears to be quite suitable, and they are now using it in routine control operations.

EDMUND THELEN

NOTES FROM THE NATIONAL BUREAU OF STANDARDS *

PREDICTION OF ELECTRONIC FAILURES

A relatively unexplored approach to the problem of insuring higher reliability of electronic equipment is being investigated at the National Bureau of Standards. With promising results, the Bureau is studying the feasibility of detecting incipient failures of equipment long before they perceptibly affect over-all performance. Quick and easy failure-prediction checks by unskilled personnel are the goal of the NBS work, which is being conducted under the sponsorship of the Office of Naval Research by J. H. Muncy of the NBS engineering electronics laboratories. A technique has been evolved experimentally in which a maintenance man simply plugs a portable failure-prediction unit into the slightly-modified equipment to be checked and turns a multi-point selector switch; a red light flashes on to identify stages or components that have deteriorated below safe levels and have become prospective causes of equipment failure. In accelerated-aging experiments on a military radio receiver, the Bureau has been able to predict most failures many hours before they occur.

As applications of radio and electronic equipment continue to increase in extent and importance, problems of maintenance and reliability become increasingly serious. This is particularly true of military electronic equipment. In addition to its importance for military communications, electronic equipment is relied on more and more by the Armed Forces for radar detection of aircraft and vessels, for the automatic aiming, firing, and detonating of weapons and missiles, and for numerous instrumentation and control applications. The inevitable complexity of much of this equipment increases the danger that failures of components will cause failures of essential equipment at critical times. Although much progress has been made toward better electronic dependability, particularly through improved-quality components, the dependability of present-day electronic equipment still leaves much to be desired. In some large and highly specialized electronic installations, such as the Whirlwind computer, valuable means for automatically detecting marginal stages have been built into the equipment. Until now, however, very little study seems to have been made of the practical possibility of detecting incipient failures by means of simple routine checks using portable test equipment.

* Communicated by the Director.

The magnitude of the problem of attaining satisfactory reliability in military electronic equipment is suggested by the fact that some large bombers now use about 2000 vacuum tubes. It has been estimated that the average home television receiver, with about 20 tubes, has an average of one tube failure for every 1200 hours of operation; if a plane with 2000 tubes had the same rate of failure, there would be one failure every 12 hours. Yet failure probabilities are increased in the plane because environmental conditions are much more severe.

Failure of electronic equipment to function properly may be caused either by sudden or by gradual failure of a tube or other component. Although improvement of quality seems to be the only way to reduce sudden failures of components, surveys have indicated that at least half of all equipment failures are produced by gradual failures of components. The NBS work has been concerned with practical means of spotting these gradual failures before the equipment becomes inoperative.

In a multi-stage equipment it is impossible in general to detect such incipient failures by input-output performance measurements. This is because the tolerances of an over-all measurement will usually mask the performance decrease of one stage that may precede failure in that stage. Daily variations in measured gain of a typical piece of equipment are greater than the change caused by the gradual deterioration of one tube in one stage; as the tube continues to deteriorate, the time at which impairment of over-all performance becomes detectable may practically coincide with the time at which over-all failure occurs. Successful failure prediction therefore requires that the condition of each important stage or small group of stages be established individually.

The designer of electronic equipment must allow certain design tolerances for the performance of any type of component, whether tube, resistor, capacitor, or complete subassembly. Component performance may vary both positively and negatively with time, and the designer must allow for these drifts as well as for initial spread. In equipment designed for reasonably long life, a component can gradually deteriorate a great deal before it reaches the level of minimum acceptable performance (the failure level). It is the gradual nature of this deterioration that gives rise to the possibility of predicting failures long in advance.

Tube failures are by far the most common cause of electronic equipment failure, and the experimental NBS failure-prediction system depends primarily on sensing decrease in tube transconductance of critical stages. This is done by operating the tube as a resistance-coupled amplifier, applying a 3000-cycle signal, and sensing whether the voltage gain has fallen below a predetermined limit. This test also detects changes in components other than the tube if the changes

are such as to affect the gain of the stage. In addition, provision is made for checking capacitors for leakage, and for voltage and current measurements, although in the equipment studied practically all the failures have been tube failures detectable by the voltage-gain check.

The military receiver selected for experimentation at NBS, an 18-stage guard-channel receiver, required only slight modification to adapt it to the failure-prediction system. The circuits were first examined for sensitivity to weak and gassy tubes. The sensitive stages were the r-f amplifier, first mixer, high i-f amplifier, second mixer, two stages of low i-f, two crystal oscillators, and two frequency multipliers. Insensitive stages were signal and avc detectors, audio and avc amplifiers, series and shunt noise limiters, and avc gate. Wiring was modified sufficiently to permit checks on the 10 sensitive stages. Changes consisted chiefly of provision for breaking grid and plate return leads to permit insertion of an audio signal and measurement of gain. Necessary connections were made to a multi-point connector into which the plug from the failure-prediction unit could be inserted. Circuit changes entailed use of only about 7.5 per cent additional components, mostly capacitors and r-f chokes; wiring and parts were all fitted without difficulty into available space in the receiver.

The experimental NBS prediction test unit includes a 3000-cycle oscillator, voltage-sensing circuits, a leakage detection circuit, and an alarm light. As the main selector switch is rotated to check the gains of the various stages of the receiver, different predetermined levels of audio signal are applied to the grid of each stage. Each input signal is preadjusted so that if the gain of the stage has changed by more than a safe amount the voltage-sensing circuits will actuate the alarm light. After the test unit has been plugged into the receiver, it takes only a few seconds to rotate the selector switch and discover any weak stages. This switching could be speeded up and made automatic by means of stepping-type switches. A separate 3-position switch on the test unit permits capacitor-leakage sensing and voltage-and-current sensing, in addition to the gain sensing. For field use the unit could be made quite compact and portable.

For laboratory evaluation of this failure-prediction system, 1000-hr. accelerated-aging tests were run at NBS on six of the modified receivers. To accelerate failures, temperatures of components were cycled between 10° C. and 120° C. with a 15-min. total period, voltages were maintained at 15 per cent above design values, and switching transients were simulated by periodically raising plate voltages to 150 per cent of normal for one second. Since the emphasis was upon producing gradual failures, vibration and shock were not included. Prediction checks were made at 5-hr. intervals.

A total of 79 tube failures occurred in the six 11-tube receivers during the 1000-hr. test period. Sixty-five of these failures, or about

80 per cent, were of a gradual and predictable nature—either low transconductance or gassiness—while the other 14 were caused by unpredictable open heaters (7) or shorts (7). The fact that other tube-failure analysis studies have shown only about 50 per cent of failures to be gradual is probably attributable largely to the presence of vibration and shock. Six of the 14 opens and shorts at the Bureau occurred during one 160-hr. period during which heaters and plates were cycled one minute on and one minute off; the other 8 were spread over 940 hours.

Fifty-eight of the 65 predictable tube failures were accurately predicted many hours before the receiver failed. Of the seven predictable failures not successfully predicted, two were in stages not being checked, four were in a single stage where parasitic oscillations interfered with measurement, and one was masked by the change in value of an overloaded resistor. Failures of components other than tubes were negligible and do not warrant any conclusions as to predictability.

The principles of measurement on which the NBS failure-prediction work has been based are not new, and many better failure-prediction systems can undoubtedly be devised; yet until now very little has been done toward developing practical techniques for semi-automatic checks to detect incipient failures. The success of the experimental work at NBS suggests that provision for simple failure-prediction routines for the maintenance of important electronic equipment deserves the serious attention of design engineers.

EFFECTS OF TANNAGE ON THE PROPERTIES OF LEATHER

Specific information regarding the effects of different tannages on the properties of leather has recently been obtained by Dr. J. R. Kanagy and associates of the National Bureau of Standards in research[1] sponsored by the Office of the Quartermaster General. Leathers tanned with chrome alone were compared with those tanned first with chrome and then retanned with vegetable tannins. The results in general indicate that each of the two types of leather has certain definite advantages and that choice of tannage should depend largely on the properties desired in the finished leather.

Both methods of tanning are widely employed in the leather industry. In general, the more rapid chrome-tanning is now chiefly used for lighter leathers such as calfskin shoe uppers and kidskins for gloves while the two-step process is used for heavier leathers such as soles, belting, and heavy uppers. As part of a program which seeks to provide improved footwear for the Armed Forces, the Army requested the

[1] For further details, see "Variation of Physical and Chemical Properties Within and Between Vegetable-Retanned Cow and Steer Hides," by J. R Kanagy, E. B. Randall, Jr., T. J. Carter, R. A. Kinmonth, Jr., and C. W. Mann, *J. Am. Leather Chem. Assoc.*, November, 1952.

Bureau to make an objective study of the characteristics of the two types of leather.

The NBS investigation included physical tests of such properties as tensile, stitch tearing, tongue tearing, and bursting strengths. Water resistance and water-vapor permeability were also determined, and chemical analyses were made for hide substance, grease content, chromic oxide and ash. Vegetable tannin content was obtained by difference. To eliminate the effect of variations due to the part of the hide from which the leather was taken, each property was determined from samples taken from 21 different sections over a side of leather.

The test results showed that the vegetable tannins tend to decrease water resistance, reduce strength, and increase thickness. However, on the whole the properties produced by use of the vegetable tannins tend to make the leather more comfortable for shoes and to increase cutting value (percentage of useable hide).

To learn more about the factors producing these effects, density determinations were made. For a variable material having a porous matrix such as leather, the density in any particular location can be expected to bear a definite relationship to the amount of fibrous material at that point, which in turn is related to the strength and other physical properties.

Although the retanned leathers contained about 20 per cent of vegetable tanning material in addition to an amount of chromic oxide approximately equivalent to that held by the straight chrome leather, the average density of the retanned leather was no greater than that of the chrome leather. It is thus apparent that a volume change must have occurred in the chrome-retanned leather. This volume change is reflected not only in the lower strength of the chrome-retanned leather, which obviously must contain less fibrous material per unit volume, but also in more uniform thickness and consequently greater cutting values.

Apparently the introduction of vegetable tannins into the leather resulted in a more hydrophylic material, as evidenced by the lower water resistance and greater water-vapor permeability of the retanned leather. Another result of the introduction of vegetable tannins was an increase in the amount of grease absorbed by the leather. This effect was to be expected since the vegetable tannins are composed of larger molecules than the chrome compounds used in tanning and are thus more effective in filling the pores in the untanned leather. Consequently, less space remains to be filled with grease.

PHONOGRAPH-NEEDLE DRAG DISTORTION

A recent study by Jacob Rabinow and Ernest Codier of the National Bureau of Standards demonstrates the existence of a type of distortion sometimes arising in phonograph reproducers—ordinary record players

—that has apparently not been treated in available literature. The Bureau's study demonstrates that, if a phonograph needle can move longitudinally (tangentially) with respect to the groove of an ordinary laterally recorded disk, the needle will not follow perfectly the lateral excursions of the groove, and "drag distortion" will result. In the playing back of recorded music, this distortion may apparently result in spurious tones of greater amplitude than the tones originally present.

The essential mechanism of drag distortion is not difficult to understand. The usual type of disk phonograph record is recorded laterally —the audio-frequency motion of the recording needle is at right angles to the record groove. For ideal distortion-free reproduction of recorded music or information, the motion of the tip of the playback needle or stylus should exactly duplicate the original lateral motion of the recording stylus. Provided the electrical output of the reproducing pickup is proportional to the lateral displacement of the reproducing stylus, the electrical output of the pickup will then be undistorted. But if forces acting on the stylus cause longitudinal motion, its lateral motion will no longer exactly duplicate the motion of the recording stylus, which means that distortion will be introduced.

Many possible causes for such longitudinal motion can be suggested. One is the well-known "pinch" effect due to the uneven width of the record groove. Another is the varying force which the sides of the record groove exert against the stylus. A third is the change in friction with changes in the pressure and velocity of the stylus in the groove.

The NBS study included both mathematical analysis and laboratory experimentation. The mathematical treatment indicates that if the recording consists of a pure tone of constant amplitude, drag distortion will introduce only even harmonics, with the second harmonic predominating. A sudden transition from one amplitude to another will produce a large change in the longitudinal force on the stylus, and this may be expected to give rise to transient distortion if the needle is not properly restrained longitudinally.

In the experimental work, a conventional crystal pickup with a replaceable steel needle was used. For some of the tests a thin steel wire was spot-welded to the needle near the tip; by tying back the needle tip with this wire, longitudinal motion could be minimized. A dual-beam oscilloscope was used to indicate simultaneously both the output of the pickup and the longitudinal displacement of the needle tip.

Two methods of measuring the longitudinal motion of the needle were tried. The first consisted of a photoelectric arrangement in which longitudinal motion of the needle modulated a beam of light. In the second and more satisfactory method, longitudinal motion of the needle frequency-modulated a 50-megacycle oscillator. Two small metal plates were mounted near the steel needle in such a way that the

capacity between the plates varied with longitudinal motion of the needle but not with lateral motion. The plates were connected across the tank coil of the oscillator, and the resulting FM signal was picked up on a standard FM receiver a few feet away. With proper tuning, the instantaneous output of the receiver varied with the instantaneous longitudinal position of the needle tip.

Various test records were reproduced with this experimental equipment. Tests were made with recordings of pure tones ranging from 20 to 10,000 cycles per second, of two different tones recorded simultaneously, and of music. The unrestrained needle showed significant longitudinal motion, substantially verifying the original hypothesis. With the equipment available, it was not possible to measure electrically the amount of distortion caused by this motion, because of the simultaneous presence of other forms of distortion. It was possible, however, to determine the magnitude of the longitudinal motion, and by computation to arrive at the character and amount of distortion attributable to this motion.

Although the effects of drag distortion can apparently be serious with some pickups, the NBS investigators point out that the styluses of the better modern pickups have high longitudinal stiffness; with such pickups, drag distortion is probably negligible.

The scope of both the mathematical analysis and the laboratory work was necessarily limited; however, the NBS work may serve as the basis for more rigorous investigation elsewhere. Although no tests were made on hill-and-dale (vertical) records and pickups, the same general considerations should apply as with lateral recordings and reproducers. It appears probable also that a form of drag distortion may arise in the recording operation if the recording stylus is not sufficiently rigid.

The NBS investigation of phonograph-needle drag distortion was a by-product of the Bureau's military research program. Telemetered information from experimental weapons is frequently recorded on disks in the NBS ordnance development laboratories, and the distortions introduced in the recording and reproducing processes are sufficiently serious at times to cast doubt on the significance of indicated measurements. Analysis of possible sources of error in these recorded measurements led to the study of distortion introduced by phonograph-needle drag.

NOTE: This work is reported in detail, with mathematical analysis, in "Phonograph Needle Drag Distortion," by J. Rabinow and E. Codier, *J. Acoust. Soc. Am.*, Vol. 24, No. 2, March, 1952.

THE FRANKLIN INSTITUTE

Minutes of the Annual Meeting

January 21, 1953

The Annual Meeting of The Franklin Institute was held on Wednesday, January 21, 1953, in the Lecture Hall of the Institute. S. Wyman Rolph, President, called the meeting to order at 8:15 P.M. Approximately 175 persons attended.

The President stated that the Minutes of the November Stated Meeting were printed in full in the December JOURNAL. No corrections or additions being submitted, they were approved as printed. He added that the Minutes of the December Stated Meeting are being printed in full in the January JOURNAL, and will be submitted for approval next month.

He also announced that the Annual Report of the Board of Managers will be presented at a meeting in the Spring after receipt of the Auditor's report.

The President called for the report of the Tellers appointed in accordance with the By-Laws to count the votes for the eight Managers to be elected. Dr. George S. Crampton, Chairman, reported that a total of 961 ballots were cast, of which 941 were legal and 20 defective, and that the nominees received votes as follows:

A. Felix duPont, Jr.	939	Lionel F. Levy	934
J. G. R. Heckscher	939	Charles Penrose	940
Clarence L. Jordan	939	R. G. Rincliffe	937
Ralph Kelly	935	Philip H. Ward, Jr.	937

The President declared that the above members were hereby elected Managers of the Institute for a term of three years. He thanked Dr. George S. Crampton, Dr. Joseph S. Hepburn, and Mr. Howard Stoertz for their services as Tellers.

The Secretary reported the following elections to membership for the month of December:

Active	19
Associate	23
Student	22

and a total Institute membership of 6626 as of December 31, 1952.

The Secretary read the following report of the Trustees of the Elliot Cresson Fund:

ELLIOT CRESSON FUND

Report of the Trustees to the
Annual Meeting of The Franklin Institute
January 21, 1953

The deed of gift under which Elliot Cresson in 1848 gave $1000 to two trustees, the income of which was to furnish medals to be awarded by The Franklin Institute, provided that the trustees should present to the annual meeting of The Institute in January a report showing the principal of the fund and its income and expenses during the preceding year. This report is submitted in accordance with such provision.

Principal of the Fund (representing the original $1000 plus transfers thereto from Unexpended Income and profit from disposition of investments)		$4,304.73
Invested as follows:		
$4000 U. S. Treasurey 2¼% bonds, due 6/15/1962–67 at book value	$4,150.03	
Cash in Western Saving Fund Society	154.70	
	$4,304.73	

Income of the Fund for 1952		
Interest on bonds (less amortization)	122.36	
Interest on bank balance	2.71	125.07
Expenses		
Medals, cases and certificates for award of two medals		173.00
Expenses in excess of income for the year		(47.93)
Unexpended income at January 1, 1952		2,329.29
Unexpended income at December 31, 1952		$2,281.36
Invested as follows:		
$2000 U. S. Treasury 2½% bonds, due 6/15/1962–67 at book value	2,075.40	
Cash in Fidelity-Philadelphia Trust Company	205.96	
	$2,281.36	

/s/ Henry B. Allen
HENRY B. ALLEN
/s/ John Frazer
JOHN FRAZER *Trustees*

The Secretary called attention to the presence in the audience of Mr. R. T. Nalle, a descendant of the first recipient of the Elliot Cresson Medal. The President asked Mr. Nalle to rise.

The President introduced Dr. John J. Grebe, Research Counselor of The Dow Chemical Company, Midland, Michigan, who spoke on "Nuclear Power and Industry." Dr. Grebe discussed the reasons why it is necessary to use atomic energy industrially, both from the point of view of its value for decentralizing industries and of producing new ones in areas not favored with low fuel costs. The approach being taken by one of the industrial teams was presented in detail. This included the reasons why they believe enough economies over currently accepted standards of costs can be produced to make it of interest for private industry to enter this field.

The meeting adjourned at 9:55 P.M. with a rising vote of thanks to Dr. Grebe.

HENRY B. ALLEN
Secretary

MEMBERSHIP

ACTIVE MEMBERS ELECTED AT THE MEETING OF THE BOARD OF MANAGERS, JANUARY 21, 1952

ACTIVE FAMILY

John Janis — Elmer H. Orttung

ACTIVE

James Booth
Joseph T. Braun
H. Russell Brownell
Rudolf E. Chope
M. W. Denkin
Maylin H. Greaser
Fred Hafner
Raymond C. Hoersch
Albin R. Jonczak
William Langer
Rear Admiral Logan Ramsey, USN (ret.)
Walter T. Scott
Carl C. Sorensen
C. R. Summers, Jr.
John S. Wood

NECROLOGY

Samuel Berman '51
Elliott Curtiss '04
Mrs. John White Geary '38
Helen D. Harbinson '37
Henry S. Harris '34
Melchior H. Horn '51
Ike Lubarsky '50
Forest Ray Moulton '38

MUSEUM

When railroads were first introduced into this country most of the locomotives were imported from England. The last order for an English-made locomotive was placed by the Reading Company for delivery of four locomotives between 1838 and 1841. The order was placed with James Braithwaite and Company, of London, George and Robert Stephenson's principal competitors. The Museum is fortunate in having the "Rocket," the first of the locomotives to be delivered, among its exhibits. This particular locomotive was landed at the port of Philadelphia, March 1838, trans-shipped by canal to Reading, where it was put to use on the Reading-Pottstown section of the line. Although this little engine weighs only 8½ tons it was remarkably well built for it remained in operation, in substantially its original form, until March 1879, having run 310,164 miles.

One of the remaining three locomotives ordered at this time had the misfortune to slip from its slings when being unloaded and fell into the river. No crane was available capable of raising it and it remained submerged until the United States Navy was able to lend a crane sufficiently strong. This locomotive was none the worse for its involuntary ducking, since its record fell little short of the "Rocket's."

American railroad engineers lost no time in designing and building locomotives that would meet the special conditions of lighter track, sharper turns, and longer grades to be encountered in this country. Their products showed marked originality and individuality. As early as 1832 Jervis introduced the leading truck, which permitted the locomotive to round sharper curves. Robert Stevens added the cowcatcher, an essential in those days of unfenced tracks. George Sellers of Philadelphia introduced a counter-balanced wheel to reduce the effect of the so-called hammer blow on the tracks. Joseph Harrison, another Philadelphian, added to the engineer's comfort and the life of the locomotive by inventing the spring and equalizer method of attaching the axles to the frame structure, which could be adapted to any number of driving wheels. This latter, and that of the leading truck, were the principal means of adapting the locomotive to American track conditions.

The whole of this remarkable series of achievements was attained within the short period of ten years, and was responsible for making the United States independent of British locomotive production.

Steam locomotives are fast disappearing from the scene. The story of their development can be followed through most of the principal innovations in the Locomotive Room of the Museum. The story begins with Blenkinsop's "Salamanca" which dragged itself along by means of a toothed wheel which engaged in pins set in the sides of the rails, and the story is carried forward to Baldwin's enormous #60,000 which was the culmination of steam railroading.

The romance of the railroad is not restricted to the development of the locomotive. Many of the supplementary details are well worth the visitor's notice. Attention might be given to the original track upon which the "Rocket" stands. This is laid on large slabs of rock and only an unexpected shortage of rocks which led to the laying of wooden ties as a temporary measure revealed the superiority of this form of track.

JOURNAL OF THE FRANKLIN INSTITUTE

The following papers will appear in this JOURNAL within the next few months:

CHANG, CHIEH-CHANG, BOA-TEH CHU AND VIVIAN O'BRIEN: Asymptotic Expansion of the Whittaker's Function $W_{k,m}(z)$ for Large Values of k,m,z.

CARPENTER, D. C.: The Reaction of Formaldehyde with D-Threonine.

ARSOVE, MAYNARD G.: The Algebraic Theory of Linear Transmission Networks.

ELDER, TAIT AND JOHN STRONG: The Infrared Transmission of Atmospheric Windows.

LAUER, HENRI: Operating Modes of a Servomechanism with Non-Linear Friction.

ZADEH, LOFTI A.: A Contribution to the Theory of Nonlinear Systems.

LIBRARY

The Committee on Library desires to add to the collections any technical works that members may wish to contribute. Contributions will be gratefully acknowledged and placed in the Library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat service. Photostat prints of any material in the collections can be supplied on request.

The Library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from 9 A. M. until 5 P. M.; Wednesdays and Thursdays from 2 P. M. until 10 P. M.

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THE FRANKLIN INSTITUTE

exists today because of the faith and generosity of the men and women who for 129 years have given time and money to its support.

The Institute welcomes financial gifts and bequests and hopes that all those who desire to perpetuate its work will make the The Institute one of their beneficiaries.

FORM OF BEQUEST

*I give and bequeath to The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, the sum of*_____

_____

V.
19

BOOK REVIEWS

INORGANIC CHEMISTRY, by Therald Moeller. 966 pages, diagrams, 16×23 cm. New York, John Wiley & Sons, Inc., 1952. Price, $10.00.

Although inorganic chemistry is one of the oldest of the experimental sciences, there are not many good advanced texts available. In part, this is due to the fact that a real knowledge of how atomic structure governs chemical properties has been developed only recently. Many good and comprehensive collections of the data have been written, but few texts have tried to organize and understand these data in terms of the underlying principles. Moeller's book does have this approach, and would be welcomed on this account alone, even if it were not an excellent book in other respects.

It is divided into two parts, entitled "Principles," and "The Chemical Elements," respectively. In Part One, the physical principles that govern chemical behavior are set forth. These principles are drawn from up-to-date quantum theory of the electronic structure of the atom. A very nice short section describes the history of the periodic table, and then shows how this periodic arrangement follows directly from the electronic configurations of the atoms. In two more chapters, data on the physical and chemical (that is, valence) regularities among the elements, as derivable from these principles, are discussed. At the end of Part One are four more or less miscellaneous chapters, covering complex ions and coordination compounds, oxidation-reduction chemistry, acids and bases, and non-aqueous solvents. A special effort has been made to organize the material on complex ions and coordination compounds.

In Part Two, the chemical properties of the elements are arranged classically, as in the periodic table. A chapter each is given to the inert gases, to hydrogen, and to the Group I and II metals. The b subgroups (the non-transition elements) of each family from III to VII are given a chapter each, while the transition and inner transition elements are each treated as a unit. Two appendices, on the properties of the naturally occurring isotopes and on members of the radioactive series, a subject and an author index are included.

The subject matter in these chapters on the chemical properties of specific groups of elements appears to be quite complete and up-to-date. Combined with the simple arrangement of the book, this gives it the character of an excellent reference book. Since it is quite thoroughly annotated, it should also be an excellent source of further reading. Within each group of elements, stress is laid upon the way in which the elements are related to and yet different from each other. These relationships are in turn shown to be due to the underlying atomic structures. At every possible opportunity, these principles are used to make the empirical data understandable and logical. This close connection between theory and data should make this also an excellent text for graduate courses in inorganic chemistry. Taken as a whole, it is a fine book, and a welcome addition to this reviewer's shelf.

ALAN D. FRANKLIN

DIRECT CURRENT MACHINES FOR CONTROL SYSTEMS, by A. Tustin. 306 pages, tables and diagrams, 14×22 cm. New York, The Macmillan Company, 1952. Price, $10.00.

Printed in Great Britain and written by Professor Tustin of the Electrical Engineering Department of Birmingham University, this new book is apropos of the times in which electrical control systems are coming into universal application throughout industry and are used widely in the vehicles of commerce.

As implied by the book's title, nine of its ten chapters deal exclusively with direct current rotating machines. The emphasis is, however, carefully placed upon "quickness of response" and those characteristics of rotating machines which are important in control systems rather than in electric power generation. The detail with which this subject is treated includes the fine points of machine design exemplified by air-gap grading. In each case the author presents a mathematical analysis of the operating parameter variations that result from such a design. Analytical methods for determining time constants of the windings of d-c. machines are

treated, showing how various factors such as distributed compensating windings influence the time constant through their effect upon the inductance.

A very obvious effort has been made by this author to bring the subject of controls using servo principles within the grasp of all electrical engineers. This attempt is assured of success inasmuch as Professor Tustin has translated the theory of feed-back systems from the language familiar to communications engineers into a form that can be better appreciated by other electrical professionals.

This does not mean that Professor Tustin's treatment of control systems is any less rigorous than the treatment of servo systems authored by communications specialists. On the contrary, the reviewer notes that operational methods are introduced on page 38, and that transfer functions serve the author in good stead throughout the remainder of the book.

This book does a first rate job of tying together the details of servo design and performance with the details of machine design for power amplification. It should be very helpful to the electrical engineer who is confronted with the selection or specification of d-c. rotating machines for control systems.

C. W. HARGENS

THERMAL DIFFUSION IN GASES, by K. E. Grew and T. L. Ibbs. 143 pages, diagrams, 15×22 cm. New York, Cambridge University Press, 1952. Price, $4.50.

The subject matter treated in this monograph is one example of the numerous cross-effects which result from the interference between matter (and/or electrical charge) flow and energy flow. thermo*dynamics* of these effects has been treated in recent books by de Groot and by Denbigh. Other examples besides "thermal diffusion" and its inverse, the "diffusion thermoeffect (Dufour effect)", are the "Seebeck thermoelectric effect" and its inverse, the "Peltier effect"; "thermomolecular pressure difference" and its inverse, the "thermomechanical effect," which are of recent interest in liquid helium II. The thermodynamic theory gives only relations between the various phenomena and their inverses, whereas the kinetic theory leads to the actual calculation of numerical values for the pertinent coefficients, these values depending of course upon the details of the particula rmolecular models used in the calculations.

The present monograph by Grew and Ibbs deals with the first-named pair of inversely related effects; namely, thermal diffusion in gases and the so-called diffusion thermoeffect discovered in 1873 by Dufour. The first chapter is a short and clear discussion of the discovery and nature of thermal diffusion. The second chapter is an outline of the essential kinetic theory of thermal diffusion and emphasizes the way in which this effect in gases depends upon the nature of the intermolecular forces. This dependence enters mathematically into the calculations, based upon a given molecular model, of the "collision integrals" which determine directly the numerical values of the coefficients of thermal and of concentration diffusion. The ratio of these is referred to as the thermal diffusion ratio and is one of the important quantities evaluated from the experiments. The third and fourth chapters discuss the experimental methods for investigating thermal diffusion, and the results obtained. Chapter 5 compares theory with experiment, emphasizing a comparison with the Lennard-Jones molecular model which consists of two radial terms, one attractive and one repulsive. Chapter 6 treats the inverse phenomenon, namely the diffusion thermoeffect, giving briefly both the experimental and the theoretical aspects. Chapter 7 treats the practical problem of gas separation by means of thermal diffusion and includes a discussion of isotope separation. Finally, Chapter 8 is concerned with thermal diffusion in liquids, an effect discovered in 1856 by Ludwig and later rediscovered by Soret. The book contains seven appendices, one of which gives Fürth's elementary theory of thermal diffusion; another one gives numerical calculations of the thermal diffusion factor for specific models; another gives a valuable list of gas mixtures which have been examined experimentally. There is also an adequate list of literature references.

The book is very well written, well illustrated, and certainly represents an excellent introduction and survey of the increasingly important field of thermal diffusion.

C. A. DOMENICALI

FATIGUE AND FRACTURE OF METALS, edited by W. M. Murray. 313 pages, diagrams, illustrations, 15×23 cm. Cambridge, The Technology Press; New York, John Wiley & Sons, Inc.; 1952. Price, $6.00.

No doubt many people have heard of the breaking in half of several merchant ships during the last war and since. During the war more than 5000 such ships were built; and about 1000 of these have had fractures of varying degrees of severity. The reasons for this brittle behavior of a ductile carbon steel—of which these ships were made—form the interesting subject matter of one of the fourteen papers comprising *Fatigue and Fracture of Metals*. The result of a symposium on the latest developments in the fatigue and fracture of metals held in June 1950 at the Massachusetts Institute of Technology, this book illustrates the importance of fatigue in many of our engineering fields. Not only is the problem of fatigue in ships discussed, but also in aircraft, in machinery and in metals in general.

Although dealing at times with specific problems in industry, the major emphasis of the book is on the nature and theory of the brittle fracture of metals. Such well known authorities in the field as O. J. Horger, E. Orowan, R. E. Peterson, N. W. Newmark, C. W. MacGregor and several foreign scientists, P. A. Jacquet and A. R. Weill of France, W. Wiehull of Sweden and P. L. Reed of England, have contributed papers to the book. The papers of Peterson (Brittle Fracture and Fatigue in Machinery), of Horger and Neifert (Internal Stresses and Fatigue), of R. L. Templin (Designing for Fatigue), and of H. L. Dryden, R. V. Rhode and P. Kuhn (The Fatigue Problem in Airplane Structures), are concerned with the phenomenological aspect of fatigue problems. On the other hand, the papers of Orowan (Fundamentals of Brittle Behavior in Metals) and of Reed (The Influence of Metallographic Structure on Fatigue) deal with the metallographic aspect of fatigue. Aware of the lengthy tests involved in obtaining empirical data on fatigue, Professor Weibull, in his paper "The Statistical Aspect of Fatigue Failures and Its Consequences," suggests a statistical approach to the problem as a means of obtaining answers more quickly. Concluding with papers on fatigue at elevated temperatures and on the techniques of physical metallurgy for studying fatigue damage, the book completes the survey of the present knowledge of fatigue quite well. While more detail may be wished at times, the copious references at the end of most of the papers afford as much material as the inquiring student demands.

E. W. HAMMER

INITIATION AND GROWTH OF EXPLOSIONS IN LIQUIDS AND SOLIDS, by F. P. Bowden and A. D. Yoffe. 104 pages, illustrations, 15×23 cm. New York, Cambridge University Press, 1952. Price, $4.50.

The problem of the origin and propagation of explosions is of great theoretical as well as practical interest. From the theoretical point of view, it provides an instance of a chemical process associated with what this reviewer has called a process of "contact motion." It, thus, represents a natural extension of the work on physical processes associated with contact motion reported in the book by Bowden and Tabor: *The Friction and Lubrication of Solids*, Oxford University Press, 1950. Its practical import lies in the fact that the commonly used empirical tests do not always provide a decisive answer as to the "safety" of an explosive under a given method of handling, leading occasionally to grievous results.

This, latest, monograph gives on 96 pages a review of the present status of the physical research on the subject. The greatest amount of space is devoted to the experimental work of the authors and their collaborators. The results of other workers in this or allied fields are included to the extent required by the logical continuity of the presentation.

The concisely and clearly written narrative is effectively supported by diagrammatical representations of a large variety of special apparatus used in the investigations; by photographs of typical test specimens and oscillograph traces; and by numerous plotted or tabulated experimental data.

The entire material is very well organized: two-thirds of the space is devoted to the subject of initiation of explosion by impact and friction, the last third to the study of the subsequent growth of an explosion into a detonation. A bibliography of 97 references and an extensive subject index make this monograph a convenient source book.

The work, which is still in progress, furnished strong evidence that in the majority of explosives the initiation of explosion is thermal in origin. That is, the mechanical energy of impact or friction must first be degraded into heat in a small region to form a "hot spot" at which a thermal ignition of the explosive then occurs. The hot spots are formed principally by: (1) adiabatic compression of small entrapped bubbles of gas; (2) friction, either on the confirming surfaces, on extraneous grit particles, or between the explosive particles themselves; (3) viscous heating of the rapidly flowing explosive escaping between the impacting surfaces.

In some primary and in all secondary explosives, the reaction initiated by a hot spot begins as a relatively slow burning. This "explosion nucleus" may be still-born or may, under favorable conditions, develop into a low-velocity detonation.

All in all, this is a most excellent little volume which will be studied with profit also by readers not directly engaged in this special field of study. OTTO R. SPIES

THE HISTORY OF ASTRONOMY, by Giorgio Abetti, translated by Betty Burr Abetti. 338 pages, illustrations, plates, 15×22 cm. New York, Henry Schuman, Inc., 1952. Price, $5.00.

The *Life of Science Library* published by Henry Schuman, Inc. passes the twenty-five volume mark with the appearance of *The History of Astronomy* by Giorgio Abetti. It is fitting that this most readable series of contributions to the history of science should achieve the quarter-hundred number with a work as useful, significant and generally engaging as this first-class translation from the Italian.

All writers on the development of the modern mind pay careful, almost reverent, respect to the part astronomy has played through the ages and the astronomers themselves are conscious of a proud tradition. It is, however, true that no up-to-date comprehensive account of the growth of this science from the beginning has been available in English.

The nearest approach has been the purely topical treatment by Peter Doig in the *Concise History of Astronomy* (London, 1950) and Angus Armitage *One Hundred Years of Astronomy* (London, 1950) which is scholarly enough but, of course, only goes back to 1850. Until now it has been difficult to improve on Agnes Clerke's article in the Encyclopedia Brittanica, old as it is, for she died forty years ago.

Those who are at home in German have had Ernst Zinner's works, the latest of which is *Astronomie Geschichte Ihres Probleme* (Munich, 1951) but the Germanic slant is strong. Even in the old Clerke, Berry, Bryant and Forbes accounts of the unfolding of ideas about the celestial bodies we have had the familiar bias of the Anglo-Saxons.

Here in the volume by Professor Abetti we find the soundest of historical sense carrying his judgment right down to contemporary astronomy. English speaking students have been familiar with his important solar researches for fourteen years, ever since *The Sun* was translated and became required reading. As director of the solar observatory at Arcetri near Florence he has not only advanced knowledge himself but has come in contact with all leading astronomers of his generation and thus can appraise their work.

It is the reviewer's duty to seek out evidence of lack of impartiality. This book deviates from the severely impartial in an expected and acceptable manner. Abetti is an Italian and he has managed to give his countrymen their due and endow them with a life in a way the drab reference with which we are familiar never could. For example, Father Secchi, founder of spectral classification and a great pioneer in astrophysics, and G. V. Schiaparelli came into their own.

Schiaparelli is remembered by the average member of The Franklin Institute, if known at all, as the man who precipitated the greatest of all astronomical controversies when he discovered the "canali" or channels on Mars and topped that by declaring some turned double. Other people are merely surprised to learn that the founder of a lucrative dress business had a clever uncle.

The fact is that Schiaparelli was an astronomer of authority who advanced his science. Such reevaluations of character are among the merits of this history. Even more important

is the fine appreciation Dr. Abetti has for trends, and schools of thought, influential in the progress of astronomy.

There is every reason to believe that *The History of Astronomy* by Giorgio Abetti will be accepted as the standard work on the subject in spite of its modest length. The author's skill is shown in his ability, even within such modest compass, to include substantial passages taken directly from astronomers' writings which help make this one of the pleasantest of all standard works to sit right down and read.

Dr. Abetti and Henry Schuman are both to be congratulated and thanked.

JOHN W. STREETER

THEORY OF ELASTICITY AND PLASTICITY, by H. M. Westergaard. 176 pages, 14×22 cm. Cambridge, Harvard University Press; New York, John Wiley & Sons, Inc.; 1952. Price, $5.00.

Written by the former Dean of the Harvard Graduate School of Engineering, this small, scholarly treatise on the theory of elasticity and plasticity contains many of the author's important contributions to these fundamental physical sciences. For many years Prof. Westergaard lectured at the University of Illinois and, since 1936, at Harvard University. This third Harvard monograph in applied science is the result of his teaching experience. Intended to be longer, it was unfortunately terminated by the author's death in June, 1950.

Beginning with a short introduction in which the basic assumptions of homogeneity and isotropy, and the correlation of theory and experiment are stressed, Prof. Westergaard continues with an outline of the historical development of the theory of elasticity. The important scientists and their significant contributions to this development are interestingly presented. Although perhaps not written so fluently as one might like, it is, nevertheless, for a short, high-lighted history of elasticity, very informative. For one who has worked with structures for some time, it is astonishing to learn that the shear center of channels and similar open sections was only discovered in the 1920's.

With this background in history, the author discusses the classical concepts of stress and strain. Proceeding further into the subject, he then discusses the strain potential with applications to such practical considerations as hollow cylinders and spheres, inertial forces and thermal forces. The remaining pages of this short book are devoted to the Galerkin vector and its application to various classical problems as Kelvin's problem of a single force applied in the interior of an extended solid, Boussinesq's problem of a normal force and Cerruti's problem when Poisson's ratio has any value.

E. W. HAMMER

ESSENTIALS OF MICROWAVES, by Robert B. Muchmore. 236 pages, diagrams, illustrations, 16×24 cm. New York, John Wiley & Sons, Inc., 1952. Price, $4.50.

Essentials of Microwaves is an elementary book on the physical principles of microwaves and microwave equipment. The author leads off with an exposition of Maxwell's equations in terms easily understood by the student of lower frequency phenomena. He then discusses and explains the operation of microwave "plumbing," antennas and tubes. In these chapters, the author makes good use of both low frequency and light analogies to help the reader bridge the gaps in his understanding of electromagnetic theory.

The chapters on microwave components are followed by a chapter on electrical noise in which the reader is made aware of the origin and effects of electrical noise, and presented with comparative data on noise figure *versus* frequency for crystals and various types of tubes used in the first state of receivers.

The application of microwave theory to systems is discussed in three chapters dealing with relay systems, radar systems, and such applications of microwaves to physical research as linear accelerators, microwave spectroscopy and the atomic clock.

The closing chapter of the book discusses microwave measurements. It deals with devices for the measurement of power, frequency, impedance, and attenuation at microwave frequencies.

To the microwave specialist as well as to the layman, this book should be of considerable interest, since it emphasizes the physical principles of microwave theory, rather than the mathematical approach to the subject.

The book is well illustrated throughout, not only with graphs and circuit diagrams, but also with cut-away views of components and photographs of microwave components and equipment.

R. S. GRUBMEYER

BOOK NOTES

MARINE FOULING AND ITS PREVENTION. 388 pages, illustrations, 21×27 cm. Annapolis, United States Naval Institute, 1952. Price, $10.00.

Prepared by the staff of the Woods Hole Oceanographic Institute for the Bureau of Ships, this monograph should be of great importance to commercial shipowners and operators, to managers of shipyards, docks and piers, to yacht owners and to manufacturers of marine construction materials and paints. It covers thoroughly the $100,000,000 a year problem of marine fouling, including an analysis of the damage it causes, a study of the biology of fouling organisms, and an important section on ways to prevent fouling. This last section contains chapters on protective devices, on the use of toxics, on the effects of various paint ingredients, and several chapters on antifouling paints. Beautifully illustrated and carefully referenced, the book is highly recommended as a worthwhile and practical contribution to marine engineering.

TABLET MAKING, by Arthur Little and K. A. Mitchell. Second edition, 123 pages, plates, 15×22 cm. Liverpool, The Northern Publishing Co., Ltd., 1952. Price, 15/.

While aimed primarily at those in the field of pharmacy, this compact treatment of tablet making is applicable in other industries, such as confectionery, cosmetics, food, plastics and powder metallurgy. The subject matter comprises a description of all processes in tablet making, including mixing, granulating, drying, compressing, coloring and coating, for all types of tablets. There are also chapters covering installation and maintenance of necessary equipment. A short chapter on formula arrangement and a formulary of 31 representative formulas concludes the book, except for a handy table of weights and measures, a glossary and an index. The many illustrative plates are well chosen and help to clarify the text. The book should serve as a reference work in this specialized field.

CHEMISTRY OF FOODS AND NUTRITION, by Henry C. Sherman. Eighth edition, 721 pages diagrams, 15×22 cm. New York, The Macmillan Company, 1952. Price, $6.00.

Recent research in the chemistry of nutrition has made it advisable for the author to revise this standard college text. In order to incorporate recent advances into this new edition, every chapter has been revised, several have been rewritten, and new chapters have been added on folic acid, vitamin B_{12}, and the citrovorum factor. The final chapter has been replaced by two new ones dealing with trends of food consumption and improvement of already normal nutrition. In this connection, it is interesting to note that some of the material used in these chapters was published by Dr. Sherman in his JOURNAL paper "Better Nutrition for More People"—part of the *Science and Tomorrow* symposium in the January 1951 issue. This new edition is highly recommended for teaching, since it reflects 40 years of the author's teaching experience.

CONTROL OF ELECTRIC MOTORS, by Paisley B. Harwood. Third edition, 538 pages, diagrams, tables, illustrations, 16×24 cm. New York, John Wiley & Sons, Inc., 1952. Price, $7.50.

In this third edition, the author has included data and diagrams on new (since 1944) devices and circuits in the motor control field. Since electronic motor control is practically an industry in itself, the material on this subject has been replaced by a chapter on regulating devices and circuits. In response to many requests, problems have been added to the text, as have meth-

ods of calculating accelerating and decelerating times and distances, both with constant torque and variable torque. In the important field of electric motor control, this revised book should be of considerable value.

INTRODUCTORY GENERAL PHYSICS, by John Gibson Winans. 765 pages, illustrations, diagrams, 16×24 cm. Boston, Ginn and Company, 1952. Price, $5.75.

Designed for a beginning text in college physics, this new book is intended for students with little background in high school mathematics and science, yet who require a workable grounding in the principles of physics. The experimental approach is emphasized, so that the student learns not only the physical principles, but also the method by which they are discovered. Tested by several years of actual classroom use, this text should prove valuable for non-science majors.

ELECTRICAL MEASURING INSTRUMENTS, PART I, by C. V. Drysdale and A. C. Jolley. Second edition, revised by G. F. Tagg, 598 pages, illustrations, tables, 16×23 cm. New York, John Wiley & Sons, Inc., 1952. Price, $12.00.

In the nearly 30 years since the first publication of this text, so many changes and advances in the electrical instruments field have taken place that a revision was imperative. The revision was done by G. F. Tagg, under arrangement with Dr. Drysdale, one of the original authors. As much of the original material has been retained as was feasible, with details of the new instruments, their design and performance, added as necessary No instruments involving electronic techniques are included, however, since the book deals only with fundamental instruments.

THE METHODS OF STATISTICS, by L. H. C. Tippett. Fourth edition, 395 pages, charts, tables, 15×22 cm. New York, John Wiley & Sons, Inc., 1952. Price, $6.00.

With the expansion of the statistical field in the past twenty years, came the need to revise the present work. In this fourth edition, the author retains the main features of the previous editions, but he has improved the exposition and filled in a few gaps. Since statistics has become so complex, it is not possible to cover the entire field rigorously; the author, therefore, has made this revision a general introduction to the methods of statistics, including references for those who wish to go beyond the text for further study. This should prove to be a useful text for a first course in statistics.

ADVANCED MECHANICS OF MATERIALS, by Fred B. Seely and James O. Smith. Second edition, 680 pages, diagrams, 16×24 cm. New York, John Wiley & Sons, Inc., 1952. Price, $6.00.

In the twenty years since the appearance of the first edition of this standard text on the mechanics of materials, many important contributions to the subject have been made. In order to include these, the authors have prepared this second edition, which is practically a new book, although the main objectives are the same as previously. This revised edition is more comprehensive than the original text, with methods of analysis and interpretation of the analyses receiving equal attention. Although the text was prepared primarily for advanced undergraduate and first year graduate students in engineering, it can be used for design and research engineers also. Many illustrative problems have been added as a means of introducing new methods or principles. The arrangement of material into chapters independent of one another makes it easy to adapt the text to courses of different lengths, content and objectives.

WOOD CHEMISTRY, VOLUME 2, edited by Louis E. Wise and Edwin C. Jahn. Second edition, American Chemical Society Monograph #97. 653 pages, 16×24 cm. New York, Reinhold Publishing Corp., 1952. Price, $15.00.

Volume 2 of this ACS Monograph is now available in the second edition. It describes—together with Volume 1—the basic chemistry underlying modern processes and products using wood or wood cellulose. Volume 2 discusses the surface properties of wood, its chemical

utilization, biological decomposition and chemical analysis. The separate chapters, written by different authorities in the field, are scholarly treatises and should be read by students in such fields as pulp and paper, rayon, cellulose, plastics, wood technology, botany and agricultural chemistry.

PHYSICAL CHEMISTRY, by Frank H. MacDougall. Third edition, 750 pages, 15×22 cm. New York, The Macmillan Company, 1952. Price, $6.00.

The author brings up-to-date his textbook of physical chemistry, in this third edition. A few minor errors have been corrected, but the chief revision has been the rewriting of the chapters on atomic structure and on reaction kinetics. The important role of quantum mechanics in the solution of chemical problems has been stressed, and the treatment of nuclear reactions has been made more comprehensive. In the field of reaction kinetics, the author added an outline of the theory of absolute reaction-rates, to help the student to understand the recent developments in this field.

HARWELL: THE BRITISH ATOMIC ENERGY RESEARCH ESTABLISHMENT 1946–1951. 128 pages, plates, diagrams, 16×25 cm. New York, Philosophical Library; London, Her Majesty's Stationery Office; 1952. Price, $3.75.

The purpose of this booklet is to present to the general reader a connected story of the work and problems of the Atomic Energy Research Establishment at Harwell from its inception in 1946 to the end of 1951. It has been impossible in this booklet to describe all the work in progress, and in some cases, particularly Chapter 8 (Fundamental Reserch Work), there has had to be a rather arbitrary selection. The reader will find that some of the work mentioned has already been published in the daily press or in scientific journals, but it has been included again, either to make an account complete, or to show the relation of the work to the program as a whole.

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NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION

ELLICE McDONALD, DIRECTOR

LACK OF EFFECT OF 2-DESOXY-D-GLUCOSE ON RAT LIVER ADENOSINETRIPHOSPHATASE AND PYROPHOSPHATASE

BY

M. H. ROSS AND JUSTINE G. ARCHER

Investigations of adenosinetriphosphatase (ATPase) and pyrophosphatase activities of rat liver homogenates were made to determine whether 2-desoxy-D-glucose (2DG) affected these dephosphorylating enzymes in the same manner as it affected alkaline phosphatase (1). An inhibition of ATPase might explain the inhibition of the glycolytic cycle in living yeast cells reported by Cramer and Woodward (2) and of growth of embryonic chicken heart fibroblasts reported by Ely (3). It has been found that 2DG, a structural analogue of glucose, had no effect on the ATPase or the pyrophosphatase activity.

Adult male rats of the Wistar strain were treated according to the procedure previously described (1) with glucose or 2DG. ATPase activity determinations were made on liver homogenates according to the method of DuBois and Potter (4). Pyrophosphatase determinations were made on liver homogenates according to the test method of Kunitz (5).

ATPase activity was not found to be significantly different in the liver homogenates from 2DG treated rats than in those from glucose treated rats (Table I). The activation of this enzyme by the addition of calcium was also not significantly different.

Pyrophosphatase activity was not found to be significantly different in liver homogeantes from 2DG treated rats than in those from glucose treated rats (Table II).

The inhibition by 2DG of glycolysis and the decrease by 2DG in the inorganic and in the organic phosphate content of the liver (1) is probably not the result of changes in the ATPase or in the pyrophos-

TABLE I.—*Rat Liver ATPase Activity.*

Intraperitoneal Injection	No. of Rats	Without Added Calcium ATPase Units Mean ± S.E.$_{mean}$	With Added Calcium ATPase Units Mean ± S.E.$_{mean}$
Glucose	15	7.69 ± 0.43	2.05 ± 0.36
2DG	15	6.64 ± 0.52	1.58 ± 0.28

TABLE II.—*Rat Liver Pyrophosphatase Activity.*

Intraperitoneal Injection	No. of Rats	Pyrophosphatase Units Mean ± S.E.$_{mean}$
Glucose	10	16.56 ± 1.54
2DG	9	18.72 ± 1.49

phatase activity since administration of 2DG to rats was not found to inhibit the activity of these enzymes in liver homogenates.

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CURRENT TOPICS

Gas Turbine Locomotive.—A gas turbine locomotive with wheels that not only turn to negotiate curves but also move from side to side under the cab for smoother riding, was reported in New York City, N. Y., recently by engineers of the Westinghouse Electric Corporation.

The experimental locomotive, which has completed more than 60,000 miles of operation on six railroads, was described in a paper presented before the American Society of Mechanical Engineers by Charles Kerr, Jr., consulting transportation engineer for Westinghouse at East Pittsburgh, Pa. Co-authors of the paper are T. J. Putz, manager of Westinghouse gas turbine engineering, South Philadelphia, Pa., and T. L. Weybrew of the firm's Transportation and Generator Division, East Pittsburgh.

"This locomotive is the first gas turbine passenger unit to be operated in the United States," Mr. Kerr declared. "It is an eight-axle, single-unit locomotive, weighing 247 tons, powered by two 2,000-horsepower gas turbines with an electric transmission."

The Westinghouse-Baldwin locomotive, he said, has a maximum speed of 100 miles an hour. During its test runs on the Pennsylvania Railroad, it pulled trains averaging 26 to 29 cars in length.

The radically new type of locomotive running gear consists of four two-axle trucks. Each of these trucks not only swivels in the usual fashion when rounding a curve, but also moves laterally under the cab of the locomotive, Mr. Kerr explained. A roller carriage is attached to each truck and the cab of the engine rests on the rollers of the four carriages, thus permitting lateral motion.

"Universally favorable comment has been received on the smooth riding and good tracking features of the locomotive," the Westinghouse engineer said. "Except for one minor change in the stiffness of a spring, no troubles with the novel running gear have been experienced," he added.

During most of its test runs, the gas turbine was operated on low grade, residual fuel oils.

"Fuel consumption in gallons," the speaker said, "has been approximately twice that of diesel locomotives in the same service." But he added: "The price paid for residual oils has varied from 3.5 cents per gallon up, depending upon location, against diesel oil prices of 8.6 cents per gallon up. Lubricating oil consumption has been practically nil.

"This locomotive is the product of an extensive development program which included first the design, construction and test of a gas turbine power plant suitable for locomotive service, followed by the construction of the locomotive, and finally road service to determine the adequacy of the design," the Westinghous engineer reported. He concluded:

"Modern diesel locomotives accumulate high mileage records which, over the life of the locomotives, may run into the millions. By these standards, the accumulated experience on this locomotive is relatively low. However,

we feel that the experience secured has been quite extensive. We have learned where changes were necessary, and in many instances, have seen our innovations prove to be very successful. We also feel that we have accomplished the purpose intended; namely, securing road experience with this type of motive power."

New Coaxial Cable System.—A revolutionary new coaxial cable system, with triple the telephone circuit capacity of those now in use, has been developed by Bell Telephone Laboratories and is undergoing exhaustive field trials prior to its installation for use in the Bell System. It is expected to go into actual service on circuits between New York and Philadelphia early in 1953.

The new system, known as "L-3" carrier, will enable one pair of coaxial pipes (pencil-size tubes of copper within the cable itself) to handle simultaneously more than 1800 telephone conversations or 600 telephone conversations plus one television program in each direction. It will be the first carrier system on which both television signals and regular telephone conversations can be sent over the same pair of coaxial pipes at the same time.

The field trials are being conducted in cooperation with the Long Lines Department of the American Telephone and Telegraph Company and associated companies of the Bell System. The equipment is being manufactured by Western Electric Company, the System's manufacturing and supply unit.

Bell Laboratories, in designing "L-3," has brought numerous advances to bear upon transmission technology. It was necessary, for example, to design new amplifiers or "repeaters," with characteristics exceeding any earlier type. In "L-3," as in earlier coaxial systems, power is fed to the repeaters over the coaxial cable from widely separated power points. The higher power requirements of the new repeaters—and the fact that twice as many are used in the new system—presented a number of technical problems.

New terminal equipment also was necessary to pile up 1800 circuits and permit both addition and subtraction of smaller groups of circuits at intermediate points. Means for putting television signals on the line and distributing them at intermediate points without introducing distortion had to be developed. Sending both television and telephone signals over the same circuits created the problem of preventing interference between the two types of signals.

Coaxial cable is one of the two types of facilities used by the Bell System in its intercity television networks. The other type is radio relay, an entirely different method of transmitting communication services. (Radio relay uses sharply focused microwave radio beams, which are transmitted serially along a chain of relay towers.) Although coaxial cable and radio relay systems are constructed primarily to meet the needs of long distance telephone service, provision is being made at the same time for television channels and other Bell System communication services where demand warrants it.

The basic coaxial cable system was the invention of two Bell Laboratories engineers, Herman A. Affel and Lloyd Espenschied, and was patented in 1931. The first experimental installation was in Phoenixville, Pa., late in 1929.

New Line of Vacuum Connectors.—Central Scientific Company announces a new line of precision-built connectors for joining tubular elements in vacuum systems. Type CHV is for making a vacuum-tight metal-to-glass connection and is especially useful for making a leak-proof seal with the glass stem of a thermocouple, Pirani, ionization or other type vacuum gage. Type CHV is hand-tightened, requiring no special wrench, and permits rapid connection or disconnection of vacuum systems. The "O" ring, which compresses to make the positive seal, is of special composition suitable for high vacuum use and temperatures to 200° F.

This new line also includes metal-to-metal connectors fitting standard tubings of steel, stainless steel, copper, etc.

The Cenco Universal Vacuum Release Valve is designed to provide a fast and convenient means of admitting air to a vacuum system. It may be connected by welding, brazing or soldering to the metal tube of the vacuum system and, if desired, may be mounted on a panel or through a plate.

Radioactive Waste Gases.—Waste gases as finally discharged into the air, from the Knolls Atomic Power Laboratory at Schenectady, N. Y., are no more radioactive than the normal surrounding atmosphere and in many instances are even less radioactive, a General Electric scientist said recently.

Speaking before the Fifth Annual Conference on Instrumentation and Nucleonics in Medicine, sponsored by the American Institute of Electrical Engineers, Joseph J. Fitzgerald described how an atomic energy laboratory can operate safely in a populated area. Mr. Fitzgerald is a scientist at the Knolls Atomic Power Laboratory, which is operated by the General Electric Company for the Atomic Energy Commission.

The laboratory is principally engaged in building a prototype atomic power plant for U. S. Navy submarines. Its research involves work with uranium 235 and other elements that release nuclear energy by the process of fission, he pointed out. A constant study is made of the waste gases discharged into the air, in order to afford the maximum protection of the neighborhood, he added.

These gases are discharged through a 100-foot stack, and are constantly monitored to make sure that the concentration of radioactive material is kept well below permissible limits, the G-E scientist said.

"Constant air monitors are located at selected sites to check the radioactive concentrations at various points near ground level. Plant samples also are analyzed on a regular schedule to evaluate the accumulation of radioactivity on vegetation," he said.

Describing the safety operations, he said that the waste radioactive gases and smokes from the working areas are first passed through a "scrubber," in which a caustic solution washes out the larger radioactive particles as well as the more volatile components. Next they go through a high-efficiency filtering system, which removes more than 99.9 per cent of the small amount of radioactive material left. The air that remains is diluted, from a thousand to ten thousand times, with filtered air from the ventilating system of the building, and then is discharged through the stack, the scientist said.

Normal atmosphere contains measurable but harmless quantities of radioactive elements, and these produce radioactive particles which are also removed by the filtering process.

"As a result," he said, "in many instances the effluent from our stack is cleaner radioactively than the atmosphere itself."

Four Watt Resistor.—A new power resistor, type PW4 rated at four watts, has been enthusiastically received as a recent addition to the International Resistance Company line. Completely insulated with an inorganic core material molded in a high temperature plastic, this unit will not support combustion. Wire element is uniformly and tightly wound on glass fiber core with axial leads 1½ in. long; 0.036 in. in diameter. Body dimensions: 1¾ in. long by 3/16 in. in diameter. Type PW4 is available from 1 ohm to 8200 ohms in ±5% and ±10% tolerance. Units prominently stamped with IRC trademark, type and rating, ohm range and tolerance. This four watt resistor is particularly recommended for television circuits requiring 2 to 3 watts actual dissipation at high ambient temperature, resistance element of resistance capacitance filter in automobile receiving sets where operation is at high ambient temperature, and all other circuits where a stable resistor is required, with wattage dissipation of 4 watts and less.

High-Speed "Brains" for High-Speed Planes.—The more that jet planes increase in speed, climbing ability, and in other aspects of performance the more assistance must be given the pilot in the way of automatic controls. These devices—such as the Westinghouse autopilot—are almost as amazing as the planes themselves. This autopilot flies the plane automatically, whether cruising leisurely or at high-speed, fast maneuvering combat. Although the autopilot contains a few tubes, its operation is based primarily on the Magamp®—magnetic amplifier.

Among the airplanes making use of the autopilot is the Lockheed F-94C Starfire, most powerful of all single-engine jets now in production. It is a two-man aircraft in the 600 mph. class and can climb to 45,000 ft. or higher. After take off, ground radar observers direct the airplane by radio toward the target. When near the target, the pilot turns on instruments which electronically track down the enemy, aim the airplane, and fire up to 24 rockets from a ring of tubes in the nose.

The Westinghouse autopilot is unique in the use of rapidly spinning "rate" gyroscopes as primary sensing elements for following the movements of the airplane during all maneuvers. They differ in this respect from ordinary "position" gyros, which are not locked to the airplane and hence resist any effort to change their direction of motion. Position gyros are sensitive only to changes in the attitude of the airplane, whereas the "rate" of gyros of the Westinghouse autopilot respond only to the rate at which such changes take place.

The flight controller of the autopilot, a single knob, affords virtual fingertip control of the movement of the airplane. To climb, the pilot pulls the knob back and the plane responds at a constant rate, regardless of external conditions. To turn, he rotates the knob either right or left. The turn is executed at once at a rate depending on the amount the knob is turned, with the correct bank angle automatically set for proper coordination.

For combat maneuvers, the pilot switches the autopilot to a mode of operation which gives him complete manual control, but which introduces the necessary rate damping to eliminate the hazard of making a maneuver

too rapidly for the high-speed aircraft. The control reacts to the pilot's signal in less than one-fifteenth second, and the hydraulic flight controls "boost" the pilot's effort some 15 times.

The autopilot works through this same system in automatically piloting the aircraft. It is tied into the plane's radar and instrument landing system, helping it to track enemy targets automatically and to land in bad weather.

The autopilot is suitable for both large and small commercial airplanes as well as military aircraft. Radio-controlled, it can also serve to direct the flight of guided missiles and pilotless aircraft.

"Hot Lab"—Atomic Age Tool.—Nuclear scientists, who work daily with radioactive materials too "hot" to handle, have been able to solve many of their problems by using one of the most unique "tools" of the Atomic Age—the "Hot Laboratory."

One such group of scientists is at work in the Bettis Plant, Pittsburgh, Pa., of the Atomic Energy Commission. This plant is operated by the Westinghouse Atomic Power Division, which is engaged in two of the nation's atomic projects—construction of the atomic power plant for submarine *U. S. S. Nautilus*, and development of another nuclear reactor for a large vessel, such as an aircraft carrier. Both projects are being conducted for the U. S. Navy and the Atomic Energy Commission.

A major problem in the construction of nuclear reactors is that of handling radioactive materials during tests and laboratory analyses. For safety purposes, this testing is done almost completely by remote control in a building known as the "hot lab."

There are five "hot spots," or cells, in the Westinghouse "hot lab" and these are separated from the main working area by a thick, concrete and lead wall. In the cells themselves—each separated from the other by a thick steel wall—are testing devices designed especially for the lab's operations.

The inside of each cell is viewed through a 36-inch-thick window comprised of layers of plate glass separated by oil. Mechanical, claw-like "hands"—controlled from outside the cell—move radioactive objects into position for testing. A periscope-telescope arrangement enables scientists to examine specimens through a remotely controlled microscope.

Transmission-Type Interference Filters.—A complete selection of transmission-type interference filters for use in isolating specific spectral bands was announced recently by Bausch & Lomb Optical Co., Rochester, N. Y.

Prominent among the fields in which this type of optical product is used are colorimetry, color densitometry, photomicrography, and flame photometry.

The filter consists of two highly reflecting but partially transmitting films of silver separated by a spacer film of non-absorbing material, deposited on a two-inch-square glass plate by the high vacuum methods pioneered by the firm. The depth of separation of the silver films by the spacer film governs the wavelength position of the "pass band"; hence the color of the light which the filter will transmit. Wavelengths carried in stock extend over the range of 340 to 800 millimicrons.

In the field of high-vacuum, thermal deposition of films on glass, Bausch & Lomb perfected techniques and formulas under the supervision of Dr. A. F.

Turner. Optical elements of binoculars, microscopes and many other optical products are now coated with anti-reflection films, some as thin as four-millionths of an inch. The thickness of the film determines its reflecting quality.

The company has prepared, for free distribution, a descriptive brochure on how to get the most out of them giving the characteristics of the new films and brief suggestions.

Giant Safe—Will Protect Precious Documents.—Three of Uncle Sam's most priceless documents will soon be put gently to bed every night in the world's largest safe, now being constructed by the Mosler Safe Company. Containing the most advanced safety features known to science, the unique safe will safeguard the irreplaceable original copies of the Bill of Rights, Declaration of Independence, and the Constitution of the United States. The giant safe, only one of its kind, will have a built-in elevator which will raise the documents every morning and lower them back into the safe every night. To make this possible, the unit's massive doors will be located on the top of the safe, which will be bomb, fire, burglary, and water-resistant. The world's largest safe, it will weigh 50 tons. Built in Mosler's Hamilton, Ohio plant, it is being installed far beneath a remodeled display shrine in the National Archives building in Washington, D. C.

During the day, visitors will be able to inspect the three priceless original documents which will be displayed in a large glass showcase on the shrine. After visiting hours, the entire show-case with its contents will be lowered by a scissors-like elevator deep down into the hidden safe. The safe's huge five-ton steel doors will automatically swing shut and lock as soon as the descending documents enter the giant safe.

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A mobile woodworking shop designed and placed in operation at the Long Beach Naval Shipyard greatly reduces time and expense involved in boat repair work, where problem has been transportation of individual machines to the work area, or carrying material to the woodworking shop. The shop consists of two units, each 5 by 14 feet, mounted on rubber-tired wheels, which can be towed to the work area. One unit carries bandsaw, jointer, table saw, drill press, overhead cut-off saw and belt sander, all connected to a central fuse box so that a 440-volt plug will activate the main switch. Second unit carries bench, vises, and necessary hardware and fittings in built-in drawers.

Hydro-ski landing gears for seaplanes will enable future "ski-planes" to taxi right out of the water and onto the beach. Retracted hydro-ski gear will give seaplanes a landplane look, and small beaching wheels built into the ski will help perform the beaching trick. Navy, Air Force, NACA and various commercial concerns have been working on this development for several years; the Bureau of Aeronautics has now released a fact sheet describing the hydro-ski project from inception to recent demonstrations. Pictures of hydro-ski landings are also available.

An Air-cooled Welding Torch designed at the Naval Engineering Experiment Station, Annapolis saves time in changing electrodes and makes it unnecessary to disconnect gas and power lines. The improved torch is small, light, constructed of insulating fiber and copper tubing; switch from electrode angle of 180 degrees to 105 degrees is quickly made by removing electrode holder, attaching angular tip to a simple threaded connection.

Wide-Angle Aerial Lens.—A new wide-angle aerial camera lens that covers a field of more than 90 degrees has been developed for the United States Air Force.

Produced by Bausch & Lomb Optical Co., Rochester, N. Y., after two years of research, the lens is known as the Cartogon. Based on a study of a prototype discovered in Germany after World War II, construction of the five-element Cartogon improves upon previous aerial camera lenses by the addition of a plane parallel element. The added element provides a better means for controlling image distortion.

Dr. Konstantin Pestrecov, chief photographic lens designer at Bausch & Lomb, says the lens "opens new possibilities in aerial mapping. It is practically distortion-free and is capable of much finer image detail than could be obtained with previous wide-angle lenses." In a special mount and given the name, Planigon, by the Air Force, the lens has been adopted by that branch of the services for "standard use in precision aerial mapping," he added.

Aluminum Bridge for Army.—Army engineers with an assist from private industry have scored a grand slam with a new aluminum fixed bridge.

The bridge, commonly referred to as the T6, is a recent development of the Army's Engineer Research and Development Laboratories at Fort Belvoir, Virginia and an outgrowth of cooperation with Aluminum Company of America and Pittsburgh-Des Moines Steel Company.

The T6 can be erected faster than any other heavy tactical bridge. It is wider and can support about 50 percent greater loads than comparable World War II bridges. With some minor changes the T6 can be used not only by a division but also by a full-dress army with its heavier equipment for spanning rivers and deep ravines.

Five years of work by the ERDL structural design staff went into the design, development and testing of a pilot model of the bridge. So successful have tests been on the experimental T6 that the Army now has the bridge under procurement.

A 75-ft. length of the new bridge can be manually erected in approximately one-third the time required for the same length of the old Bailey bridge, according to Howard H. Mullins, Chief of the Civil Engineering Group. He further revealed that, maintaining division load capacity, the T6 can span approximately 180 ft.

One reason for the record breaking construction time for the bridge prototype was aluminum's light weight, approximately 60 per cent of the weight of a comparable steel bridge. Another is simplicity of detail. Also, during the latter part of World War II Aluminum Company of America and the Army's Engineer Laboratories cooperated in the development of the M4 aluminum floating bridge, which has been used in Korea, and this cooperation was continued after the war in the development of the heavy tactical or fixed bridges culminating in the T6.

The Pittsburgh-Des Moines Steel Company fabricated the engineering test model of the bridge. This was subjected to structural, construction and transportation tests, prior to operational field testing by a troop unit.

Revolutionary feature of the T6 is its easy adaptability from divisional use to use by a full-dress army, which includes a number of divisions. Ordinarily the heavier equipment of an army cannot be transported over a division bridge. It can be carried by the T6 to which panels must be added, however.

BY-LAWS

ARTICLE I

Stock

Section 1. The Real and Personal Estates of the Institute as held upon the First day of January, One Thousand Eight Hundred and Eighty-one, shall be valued at One Hundred Thousand Dollars, and shall be represented by Ten Thousand Shares of Stock of the par value of Ten Dollars each. Said shares shall be divided into two classes, *viz.:*

First Class. Shares not registered for use: on which no annual payment shall be charged or collected, and the holders thereof shall not have the privileges of members of the Institute, but may, if of legal age, vote at any annual election for managers upon the payment of One Dollar upon each share of stock on which they may desire to vote; provided, however, such shares have been held by the same person at least three months before such election.

Shares of the First Class may be converted into shares of the Second Class at the pleasure of the owners, provided the transfer be approved by the Board of Managers; but, when once so converted, they shall always continue in the Second Class.

Second Class. Shares registered for use: on which Twelve Dollars per annum shall be due and payable from resident members in advance on the first day of October in each year, except as hereinafter provided.

Non-resident holders of Second Class stock shall pay an annual fee of Five Dollars.

Section 2. The holders of Second Class stock shall be entitled to the use of the library, lectures and reading-room, and if of legal age, to all other privileges of membership in the Institute, so long as they make the annual payment in advance; and shall, on the payment of One Dollar therefore, be entitled to a Certificate of Membership.

Section 3. If the annual dues for successive years remain unpaid at the expiration of two and a half years on any share of stock of the Second Class, such shares shall then become forfeited to the Institute; but such forfeiture may be remitted by a unanimous vote of the Board of Managers.

Section 4. Stock of the Second Class may be held in trust for persons not of legal age, and shall be liable to the payment of only one-half the annual fees due upon stock of Second Class held by persons of legal age; provided, that when such minors arrive at legal age, new certificates, subject to the full annual contribution, shall issue on payment of the customary fee.

Section 5. Certificates for the First Class stock may be issued for any number of shares in a single certificate; but every certificate for the Second Class shall be for one share only.

Section 6. No share of stock in the Second Class shall be transferred until all arrearages and fines are paid, and all books and tickets returned, and the transfer approved by the Board of Managers.

Section 7. All certificates of stock shall be signed by the President and Secretary; shall be issued by the Controller, and shall be transferable only on the books of the Institute by the owner, or his legal representative, on the surrender of the old certificate, and of a fee of twenty-five cents for each certificate.

Section 8. All subscriptions to stock shall be approved by the Board of Managers before the certificate can be issued.

ARTICLE II

Members

Section 1. All persons interested in the purposes and activities of the Institute and willing to further them may become members when elected by the Board of Managers, or in a manner prescribed by the Board, except as qualified by Section 6 of this Article. Membership shall consist of the following classes:

1. Student members
2. Associate members
3. Active members
4. Sustaining members
5. Honorary members

The Board of Managers may establish other classes of members, provided that the privileges enjoyed and dues paid by such other classes are not inconsistent with the privileges and dues of the classes of members specifically provided for by these By-Laws.

Section 2. Student members shall be under twenty-five years of age and shall pay annual dues of $2.00. They shall be entitled to unlimited free admission to the Museum and the Planetarium. Student members who are fourteen or more years of age may, if endorsed by a teacher or an Active member, have the use of the library upon the payment of additional annual dues of $1.00 but shall have no voting privileges or rights to hold office.

Section 3. Associate members shall pay annual dues of $5.00. They shall be entitled to unlimited free admission to the Museum and to the Planetarium, but shall have no voting privileges or rights to hold office. Upon the payment of $5.00 additional annual dues they shall have Family privileges as defined in Section 7 of this ARTICLE.

Section 4. Active members shall be not less than twenty years of age. They shall pay annual dues of $15.00. Active members, residing permanently at a distance of fifty miles or more from Philadelphia, shall pay annual dues of $7.50. Active members shall be entitled to use the library, to receive one copy of the *Journal of The Franklin Institute*, to vote and to hold office. They shall be entitled to all the privileges of Associate members and upon the payment of $5.00 additional annual dues shall be entitled to Family privileges.

Section 5. Sustaining members shall be not less than twenty years of age. They shall pay annual dues of not less than $50.00. They shall be entitled to all of the privileges of Active members and shall have Family privileges as defined in Section 7 of this ARTICLE free of additional charge.

Section 6. Honorary members shall be entitled to all of the privileges of sustaining members, except the right to vote and to hold office. They shall be nominated by the Board of Managers and shall be elected by four-fifths of the votes of the members present at any stated meeting of the Institute at which their nomination may be acted upon.

Section 7. Family privileges consist of the right to receive a card for each individual in the family of the member and resident with the member entitling the holder to unlimited free admission to the Museum and the Planetarium.

Section 8. Members belonging to classes of membership existing prior to the amendment of this ARTICLE shall be reclassified in a manner consistent with their former dues and privileges.

ARTICLE III

PAYMENT OF DUES

Section 1. The annual fees for membership shall be due and payable on the first day of each month, whichever is nearest to the date of election or as determined by the Board of Managers.

Section 2. Any member whose dues are more than two months in arrears shall have all the privileges of membership suspended until such time as all arrears are paid. Should the dues not be paid when they become six months in arrears the said member shall forfeit his membership.

Section 3. The Board may remit temporarily in whole or in part the dues of any member either by action in a particular case or by establishing regulations governing certain cases.

Section 4. Every person admitted to membership in the Institute shall be considered as liable for the payment of dues until he shall have resigned, been dropped or have been relieved therefrom by the Board of Managers.

Section 5. Resignations of memberships shall be made to the Board of Managers in writing, but need not be accepted until all dues and arrears up to date of resignation shall have been paid.

Section 6. The privileges and title of Associate member may be obtained for life by paying therefor in one year the sum of $100. From this payment may be deducted one-half of the Student or Associate Membership dues paid by the member during the preceding ten years, but in no case shall the deduction exceed $50.00.

Section 7. The privileges and title of Active Member shall be enjoyed for life or may be obtained for life by a member who has heretofore or who shall hereafter pay therefor, in one year, the sum of $300, except

that a person residing permanently at a distance of twenty-five miles or more from Philadelphia may become an Active Member for life by paying therefor in one year the sum of $100. From this payment may be deducted one-half of the dues paid by the member during the preceding ten years, but in no case shall the deduction exceed one-half of said payment. Associate Members for life may become Active Members for life by paying therefor in one year the sum of $200.

Section 8. Firms, corporations, associations or individuals may nominate and subscribe for the membership dues of groups of members of any class or classes, at the annual dues provided for, subject to the approval of the Board as to any particular nominee. If the dues of these nominees amount to $100 or more in the aggregate, the firm, corporation, association or individual shall be known as an Affiliate of the Institute.

ARTICLE IV

MANAGEMENT

Section 1. The Institute shall be governed by a board of twenty-four (24) Managers elected by the members.

Section 2. The officers, who shall be elected by the Board of Managers, shall be a President, an Executive Vice President, not more than five Vice Presidents, a Secretary, an Assistant Secretary, a Treasurer, and an Assistant Treasurer. The Board of Managers may elect such other officers as it deems necessary.

Section 3. At the annual meeting of the Institute, eight Managers shall be elected each year to serve for three years, provided that the Managers now elected, or who may hereafter be elected, shall continue to serve until their successors be appointed.

Section 4. All elections of the Institute shall be by letter ballot and no vote may be cast by proxy.

Section 5. Nominations for Managers shall be made in writing at the stated meeting in the month of December. Each nomination paper must be signed by at least two members, who shall certify that the candidate will serve if elected. After the nominations are closed, the President shall appoint three members, who are neither officers nor nominees, to act as tellers of election. The list of nominees shall be posted at the Institute and incorporated (with directions for voting) in a ballot to be sent to each member by the Secretary at least one week before the date of election. Each ballot shall be accompanied by a return envelope addressed "To the Tellers of Election," and provided with a space for the signature of the member voting.

Section 6. On the date of the annual meeting, and at an hour previously designated by their chairman, the tellers shall meet at the Institute, and shall count all legal votes that have been received by mail or placed in the ballot box before eight o'clock P.M.; and when the count is completed they shall report to the annual meeting of the Institute the total number of ballots cast, together with the number of votes received by each candidate. Thereupon the presiding officer shall announce the names of the candidates who received the plurality of votes, and shall declare them elected Managers of the Institute for the ensuing terms.

Section 7. At the organization meeting of the Board of Managers, the Board of Managers shall elect the officers provided for in Section 2 of ARTICLE IV to serve for one year; and may at said organization meeting or from time to time thereafter elect such other officers as it may determine upon, and shall determine and fix the compensation, if any, to be paid to the officers so elected or appointed by them. The officers who are in office immediately prior to the annual meeting shall continue in office until their successors are elected or appointed by the Board of Managers as herein provided.

Section 8. Vacancies occurring in any office may be filled by the Board of Managers by election or appointment of persons to serve until the next annual election.

ARTICLE V

BOARD OF MANAGERS

Section 1. The Board of Managers shall have general charge and control of the Institute and of the Benjamin Franklin Memorial and The Franklin Institute Museum, and shall consist of twenty-four members elected as provided in ARTICLE IV. The President, the Executive Vice President, the Vice Presidents, the Secretary, the Treasurer, the Chairman of the Committee on Science

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and the Arts, and the Chairman of the Library Committee shall be *ex officio* members. A quorum of the Board of Managers shall be nine of the elected and *ex officio* members. The Board of Managers may adopt such by-laws, rules and regulations for the governance of their affairs as are not inconsistent with the Charter and these By-Laws.

Section 2. They shall present, through the President, at the annual meeting of the Institute, a report of the condition of the affairs of the Institute.

Section 3. They shall hold stated meetings in each month except in July and August.

Section 4. Special meetings may be called by the President at his discretion and shall be called by him on written request of the Executive Committee or of any seven members of the Board. In case of his absence or refusal to act, such special meeting shall be called by the Secretary.

Section 5. Members who have not attended five regular meetings in the twelve months prior to the stated meeting of the Institute in December, shall be reported thereat as having resigned, unless it be unanimously voted by the Board at that meeting that such member has been absent for sufficient reason.

Section 6. All vacancies on the Board of Managers shall be filled by the Board until the next annual meeting of the Institute.

Section 7. The Board of Managers may elect an Executive Committee consisting of five of its Members with such authority to act on behalf of the Board as the Board may delegate.

ARTICLE VI

DUTIES OF OFFICERS

Section 1. The President shall be the executive head of the Institute and, under the supervision of the Board of Managers, shall have general charge of the affairs of the Institute. He shall preside at all meetings of the Institute and of the Board of Managers and shall be, *ex officio*, a member of all standing committees of the Institute.

Section 2. The Executive Vice President, under the supervision of the President, shall have immediate charge of all affairs of the Institute other than those matters specifically delegated by action of the Board of Managers pursuant to these By-Laws to the Executive Committee and the Finance Committee. He shall prepare the annual budget, and submit it to the Board of Managers for approval. He shall be an *ex officio* member of all standing Committees of the Institute. He shall report to the President. In case of the disability of the Executive Vice President, the President shall designate another officer or other officers to assume his duties.

Section 3. In the absence of the President, the Executive Vice President shall exercise his duties. In the absence of both the President and the Executive Vice President, the Vice Presidents shall exercise the duties of President in order of their seniority in office.

Section 4. The Secretary shall be responsible for keeping the minutes of all meetings of the Institute and of the Board of Managers, shall keep the records of the Institute, and shall perform all the duties usually pertaining to the office of Secretary. He shall report to the Executive Vice President. In the absence or disability of the Secretary, the Assistant Secretary shall perform his duties.

Section 5. The Treasurer shall have custody of all monies received from the Committee on Finance together with all monies received by the Institute from dues, admissions, and other operations of the Institute, depositing them, in the name of the Institute, in such bank or banks as the Board of Managers shall direct and disbursing them by checks signed as the Board of Managers shall likewise direct. He shall keep accounts of the receipts and disbursements and shall report thereon to the Board of Managers as directed. He shall have general supervision of the accounts of the Institute and shall render such financial statements as directed by the Board of Managers. He shall give bond to an amount and with such surety as the Board of Managers shall determine. The Treasurer shall report to the Executive Vice President. In the absence of the Treasurer, the Assistant Treasurers shall, in the order of their seniority in office, perform his duties.

ARTICLE VII

BOARD OF COUNCILLORS

The Board of Councillors shall consist of not more than fifty members and shall embrace, as *ex officio* members, the Governor of

Pennsylvania, the Chief Justice of the Supreme Court of Pennsylvania, the Mayor of the City of Philadelphia, the President of the City Council of Philadelphia, the President of the Board of Public Education and the Superintendent of Schools of the City of Philadelphia, the Provost and the President of the University of Pennsylvania, the President of Commissioners of Fairmount Park, the President of the American Philosophical Society, the President of the Poor Richard Club, and the President and Secretary of The Franklin Institute, which two latter shall respectively be Chairman and Secretary of the Board of Councillors. Additional members shall be nominated by the President or Secretary of the Institute and elected by the Board of Managers, at such intervals as the Board of Managers may see fit. The Board of Councillors shall meet at the call of its Chairman or of the Board of Managers for the consideration of any matter that pertains to the welfare of the Institute. The Secretary shall from time to time send to the members of the Board of Councillors a report of the activities and accomplishments of the Institute.

ARTICLE VIII

COMMITTEES OF THE INSTITUTE

Section 1. There shall be the following Standing Committees of the Institute:

1. Bartol Research Foundation Committee.
2. Biochemical Research Foundation Committee.
3. Committee on Science and the Arts.
4. Endowment Committee.
5. Finance Committee.
6. Library Committee.
7. Meetings Committee.
8. Membership Committee.
9. Museum and Memorial Committee.
10. Publications Committee.
11. Committee on Research.

Section 2. Each standing committee of the Institute shall consist of the number of members determined on by the Board of Managers and composed of members of the Board of Managers and/or non-members as may be desirable, except that the Committee on Science and the Arts shall consist of not less than sixty nor more than seventy-five members, and except that the Bartol Research Foundation shall consist of not less than ten nor more than fifteen members as provided for in Section 7 of this ARTICLE.

Section 3. The members of each committee shall serve one year, except that members of the Committee on Science and the Arts shall serve three years.

Section 4. The members of each committee, other than *ex officio* members specifically provided for by these By-Laws, shall be appointed by the President and approved by the Board of Managers at the organization meeting of the Board following the annual meeting except that each year but one-third of the total number of members of the Committee on Science and the Arts shall be so appointed and approved.

Section 5. The Chairman of each Committee shall be designated by the President, except that the Library Committee and the Committee on Science and the Arts shall select their chairmen. A chairman who is not an elected or *ex officio* member of the Board of Managers shall have the privilege of the floor at meetings of the Board but shall not have the right to vote.

Section 6. Each Committee shall report monthly to the Board of Managers through its Chairman. A copy of their report shall be in the hands of the Executive Vice President one week before the monthly meeting of the Board.

Section 7. The Bartol Research Foundation Committee shall consist of not less than ten nor more than fifteen members, including the President and the Executive Vice President of the Institute and the Director of the Bartol Research Foundation as *ex officio* members and nine members of the Institute of whom not more than four shall be members of the Board of Managers. The Committee shall, after consultation with the Director of the Bartol Research Foundation and subject to the approval of the Board of Managers, collaborate with the Executive Vice President in carrying out the purposes and determining the policies of the Bartol Research Foundation. It shall appoint the Director and the Staff of the Laboratories, subject to the approval of the Board of Managers. The Director of the Bartol Research Foundation, to whom all other employees of the Founda-

tion shall report, shall have charge of the scientific activities of the Foundation and shall report on all matters to the Committee or to the Executive Vice President, as the Committee may elect.

Section 8. The Biochemical Research Foundation Committee shall report to the Board of Managers from time to time on the condition of the affairs and operation of said Foundation and shall be available to the Director of the Biochemical Research Foundation and its Advisory Council for collaboration and advice.

Section 9. The Committee on Science and the Arts shall investigate current discoveries, inventions and other achievements in the sciences and their application in the mechanical and industrial arts with a view of affording such recognition as may lie within the power of the Institute to bestow. The Committee shall exercise independent judgment therein. In all matters of a general or administrative nature the Committee shall collaborate with the Executive Vice President.

Section 10. The Endowment Committee shall, in collaboration with the Executive Vice President, encourage the gift of funds to the Institute.

Section 11. The Finance Committee shall have the custody and control of all the securities and investments of the Institute with full power and authority to buy and to sell, and to invest and reinvest the same; including the power to satisfy mortgages and extinguish ground rents, and to direct the placing of all such insurances on Real Estate for investment as it may deem necessary, and to make such improvements, repairs and alterations to such Real Estate as it may deem necessary. It shall have power to authorize the proper officers of the Institute to execute the necessary papers to effect all purchases, sales and assignments of property other than real estate; to transfer registered securities; to subscribe to bond-holders' agreements to plans of reorganization involving any securities held by the Institute or in which it has an interest; and to do all such acts as are necessary in pursuance of the foregoing powers. It may, with the approval of the Board of Managers, appoint a Trust Company of the City of Philadelphia to act as Fiscal Agent under the direction of the Committee.

The Finance Committee shall keep a record of all its acts and proceedings, which shall be communicated to the Board of Managers.

Section 12. The Library Committee, in collaboration with the Executive Vice President, shall be of counsel and advice in the purchase of books and publications suitable to and consonant with the purposes of the Library; and in other matters pertaining to the Library.

Section 13. The Meetings Committee shall, in collaboration with the Executive Vice President, secure for presentation before the Institute papers dealing authoritatively with subjects of import in the fields of science, engineering and industry.

Section 14. The Membership Committee shall, in collaboration with the Executive Vice President, promote the several memberships defined in ARTICLE II of these By-Laws.

Section 15. The Museum and Memorial Committee shall, in collaboration with the Executive Vice President, be of counsel and advice to the Director of the Benjamin Franklin Memorial and The Franklin Institute Museum, and with the scientific staff of the Museum concerning the activities and the exhibits of both the Museum and the Memorial.

Section 16. The Publications Committee, in collaboration with the Executive Vice President, shall be of counsel and advice with regard to all publications of the Institute other than publications of the Bartol Research Foundation.

Section 17. The Committee on Research shall, in collaboration with the Executive Vice President, be of counsel and advice to all research activities of the Institute except those of the Bartol and Biochemical Foundations.

Section 18. Each committee shall organize and adopt rules as it sees fit, subject to the provisions of these By-Laws and the approval of the Board of Managers.

ARTICLE IX

MEETING

Section 1. The Institute shall hold stated meetings on the third Wednesday of each month, except in June, July, August and September, at 8:15 P.M.

Section 2. Special meetings shall be called by the President upon the order of the Board

of Managers or within ten days upon the written application of twenty-four voting members of the Institute.

Section 3. Twenty-four members shall constitute a quorum at any stated or special meeting.

Section 4. The Annual Meeting of the Institute shall be held on the third Wednesday of January of each year at 8:15 P.M. Elections at Annual Meetings shall not result from the poll of less than forty-eight ballots cast in accordance with ARTICLE VI, Section 6, of these By-Laws.

ARTICLE X

AMENDMENTS

These By-Laws may be altered or amended at any stated meeting of the members of the Institute, provided notice in writing, signed by two members, of the proposed alteration or amendment, shall be given to the Board of Managers two months prior to the said meeting, except that amendments to ARTICLE I, relating to capital stock, must be ratified subsequently by a majority of the stock represented at a meeting specially called for this purpose.

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